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Device Infection Imaging with Fluorine-18 Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography in Patients with Left Ventricular Assist Device

Sol Ventrikül Destek Cihazı Enfeksiyonlarının Flor-18 Florodeoksiglukoz Pozitron Emisyon Tomografisi/Bilgisayarlı Tomografi ile Görüntülemesi

ABSTRACT

Objective: Left ventricular assist devices (LVADs) significantly improve survival in advanced heart failure; however, infectious complications remain an important clinical challenge, with reported sepsis rates ranging from 20–40% within 1–2 years. Early and accurate identification and localization of infections—particularly at the driveline or pump—are essential for guiding treatment.

Method: We retrospectively evaluated fluorine-18 (F18) fluorodeoxyglucose (FDG) positron emission tomography/computed tomography (PET/CT) scans of 15 patients with suspected LVAD infection. We assessed the presence and localization of infection (driveline vs. pump), its extent, and compared PET/CT findings with microbiological culture results.

Results: F18 FDG PET/CT demonstrated 100% sensitivity, 66% specificity, 92% positive predictive value, and 100% negative predictive value. Thirteen of 15 patients (87%) had positive PET/CT findings, with a mean SUV_{max} of 7.73. Infection was localized to the driveline in 10 patients and to both pump and driveline in 3. PET/CT findings were consistent with culture results, which identified *Staphylococcus aureus* and *Pseudomonas aeruginosa* as the predominant pathogens.

Conclusion: F18 FDG PET/CT is a highly sensitive, noninvasive modality for detecting and localizing LVAD infections. It aids clinicians in optimizing management strategies—such as device exchange or targeted antibiotic therapy—and may help avoid unnecessary invasive procedures. In cases of pump infection, this imaging modality supports timely interventions, including consideration for heart transplantation.

Keywords: Driveline, fluorine-18, fluorodeoxyglucose, infection, left ventricular assist device, maximum standardized uptake value, positron emission tomography/computed tomography, pump infection

ÖZET

Amaç: Sol ventrikül destek cihazları (LVAD) ileri kalp yetmezliğinde sağkalımı önemli ölçüde iyileştirir, ancak enfeksiyöz komplikasyonlar önemli bir klinik zorluk olmaya devam etmektedir ve bildirilen sepsis oranları 1-2 yıl içinde %20-40 arasında değişmektedir.Enfeksiyonların özellikle driveline veya pompa lokalizasyonlarında erken ve doğru saptanması, tedavi stratejileri açısından kritik öneme sahiptir.

Yöntem: Bu retrospektif çalışmada LVAD enfeksiyonundan şüphelenilen 15 hastanın F18 FDG PET/BT görüntüleri analiz edilmiştir. Görüntülerde enfeksiyon varlığı, lokalizasyonu (driveline vs. pompa), yayılımı değerlendirilmiş ve mikrobiyolojik kültür sonuçları ile karşılaştırılmıştır.

Bulgular: F18 FDG PET/BT, %100 duyarlılık, %66 özgüllük, %92 pozitif prediktif değer ve %100 negatif prediktif değer göstermiştir. 15 hastanın 13'ünde (%87) PET/BT pozitif bulunmuş; ortalama SUV_{max} 7,73 olarak belirlenmiştir. On hastada enfeksiyon yalnızca driveline'de, üç hastada ise hem driveline hem pompada lokalize edilmiştir. Görüntü bulguları, kültür sonuçları ile uyumlu olup, başlıca etkenler *Staphylococcus aureus* ve *Pseudomonas aeruginosa* olarak saptanmıştır.

Sonuç: F18 FDG PET/BT, LVAD enfeksiyonlarının saptanması ve lokalizasyonunda yüksek duyarlılığa sahip non-invaziv bir yöntemdir. Klinik karar süreçlerinde—örneğin cihaz değişimi veya hedefe yönelik antibiyotik tedavisi gibi—yol gösterici olabilir; özellikle pump enfeksiyonlarında gereksiz invaziv işlemleri önleyerek, kalp nakli gibi zamanlı müdahaleleri destekleyebilir.

Anahtar Kelimeler: Driveline, flor-18, florodeoksiglukoz, enfeksiyon, sol ventrikül destek cihazı, maksimum standart alım değeri, pozitron emisyon tomografisi/bilgisayarlı tomografi, pompa enfeksiyonu

ORIGINAL ARTICLE
KLİNİK ÇALIŞMA

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Left ventricular assist devices (LVADs) are widely used in patients with advanced heart failure as a bridging treatment for cardiac pre-transplantation. They play a critical role in disease management for this group of patients due to the shortage of donor hearts for transplantation.[1] Left ventricular assist devices significantly improve survival in advanced heart failure; however, infectious complications remain an important clinical challenge, with reported sepsis rates ranging between 20–40% within 1–2 years.[2] A left ventricular assist device is powered by a cable that passes through the skin (percutaneous driveline). The exit point of this cable from the skin (driveline exit site) provides a potential route for bacterial entry into the bloodstream. Driveline infections are the most common among LVAD-related infections. When infection spreads along the driveline to the central elements of the device and intrathoracic components (such as the cannula/tube carrying blood to the aorta and the pump), it becomes very difficult to manage and treat. This often necessitates device removal and heart transplantation. However, if the infection is peripheral or extrathoracic, antibiotic therapy and debridement may be sufficient.[3] Blood cultures, computed tomography, echocardiography, and laboratory and clinical infection findings are often insufficient for early detection and localization of infection. Fluorine-18 fluorodeoxyglucose positron emission tomography/computed tomography (F18 FDG PET/CT) has been shown to have high sensitivity in localizing infection.[4] The aim of this study is to evaluate the detection and extent of infection in patients with suspected LVAD infection using F18 FDG PET/CT.

Materials and Methods

Ethical Approval and Patient Consent

This study was approved by the Ümraniye Training and Research Hospital Scientific Research Ethics Committee (Approval Number: B.10.1.TKH.4.34.H.GP.0.01/221, Date: 10.07.2025). Written informed consent was obtained from all participants prior to their inclusion in the study. All procedures were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Patient Selection

F18 PET/CT images of 15 patients (1 female and 14 males) who presented to our clinic with clinical suspicion of LVAD infection between 2019 and 2023 were evaluated retrospectively. The average age of the patients was 51 years (range: 38–65). None of the patients were receiving antibiotic therapy at the time of imaging. Patients with clinical suspicion of infection were referred to our clinic to determine the localization and extent of infection. The presence of infection was suspected based on clinical and laboratory findings.

Patient Preparation Before PET/CT Examination

Physiological glucose uptake by myocardial tissue is a limiting factor in imaging cardiac infections using F18 FDG PET/CT. A low-carbohydrate, high-fat diet is recommended for cardiac infection imaging.[5,6] All patients followed a low-carbohydrate, high-protein, and high-fat diet for 72 hours prior to the PET/CT scan.

ABBREVIATIONS

CRP	C-reactive protein
EANM	European Association of Nuclear Medicine
F18	Fluorine-18
FDG	Fluorodeoxyglucose
ISHLT	International Society for Heart and Lung Transplantation
LVAD	Left ventricular assist device
MRI	Magnetic resonance imaging
NAC	Non-attenuation corrected
NPV	Negative predictive value
OSEM	Ordered Subset Expectation Maximization
PET/CT	Oositron emission tomography/computed tomography
PPV	Positive predictive value
SUV_{max}	Maximum standardized uptake value
VAD	Ventricular assist device

PET/CT Examination

Patients' blood sugar levels were measured after fasting for at least 6 hours, and imaging was performed only if levels were below 170 mg/dl. Intravenous injection of F18 FDG was administered at a dose of 5 MBq/kg. After an uptake period of approximately 1 hour, images were acquired using a GE Discovery 600 PET/CT scanner. Low-dose CT images were obtained from the head to the mid-thigh. After CT images were obtained, PET images were acquired for each bed position for 3 minutes. Images were reconstructed using the OSEM (Ordered Subset Expectation Maximization) filter. Attenuation correction was performed with CT images, and GE's Volume Viewer software was used for reconstruction and processing.

PET/CT Image Analysis

The pump and cannula located in the intrathoracic area, as well as the surrounding intrathoracic and abdominal portions of the driveline, were visually evaluated on PET/CT images. FDG uptake higher than the physiological uptake of the liver was considered positive. Areas showing increased FDG uptake were confirmed with non-attenuation corrected (NAC) images and recorded as positive uptake. The maximum standardized uptake values (SUV_{max}) of positive involvement areas were calculated. PET metrics include regional semiquantitative indices, such as the SUV_{max}, which represents the pixel with the highest FDG uptake activity.

Definitive Diagnosis of Infection

The definitive diagnosis of LVAD infection was determined during patient follow-up based on microbiological culture results obtained from the pump and/or driveline components (Table 1). Data were accessed from the national health database (e-Nabız).

All acquisitions and evaluations were performed in accordance with the European Association of Nuclear Medicine (EANM)/EANM Research Ltd. (EARL) procedural guidelines for infection and inflammation imaging.

Results

PET/CT Findings

In 12 of 13 patients with involvement detected on PET/CT, laboratory data and infection parameters were high. The average SUV_{max} value among the 13 patients with positive findings was

Table 1. Patients' table

Patient no	Age	CRP / WBC	Culture	PET/CT	SUV_{max} values	Involvement sites in PET/CT	Clinical infection decision	Treatment	Result
1	38	30.4/4.6	+	+	8.93	Driveline	+	Antibiotic treatment	True positive
2	38	3.1/7.6	–	+	5.17	Driveline	–	Wound care, medical dressing	False positive
3	40	47,98/11.9	+	+	11.15	Driveline	+	Antibiotic treatment	True positive
4	40	19.06/9.01	–	–	–	–	–	Wound care, medical dressing	True negative
5	64	46/9.18	+	+	5.06	Driveline	+	Antibiotic treatment	True positive
6	59	191.1/12.56	+	+	7.52	Pump and driveline	Mediastinitis	Pump and driveline change	True positive
7	59	76.12/8.19	+	+	15.11	Driveline	+	Antibiotic treatment	True positive
8	62	212.0/20.07	+	+	6.0	Driveline	+	Antibiotic treatment	True positive
9	38	42.16/4.95	+	+	10.13	Pump and driveline	Mediastinitis	Pump and driveline change	True positive
10	42	32.1/11.8	+	+	2.76	Driveline	+	Antibiotic treatment	True positive
11	65	53.08/6.3	+	+	3.91	Driveline	+	Antibiotic treatment	True positive
12	53	2.6/5.7	–	–	–	–	–	Wound care, medical dressing	True negative
13	55	27.3/8.2	+	+	5.41	Driveline	+	Antibiotic treatment	True positive
14	62	36.4/9.1	+	+	3.23	Driveline	+	Antibiotic treatment	True positive
15	62	87.52/14.2	+	+	16.20	Pump and driveline	Mediastinitis	Pump and driveline change	True positive

CRP, C-reactive protein; WBC, White blood cell; PET, Positron emission tomography; CT, Computed tomography; SUV_{max}, Maximum standardized uptake value.

7.73 (range: 2.76–16.20) (Table 1). In one patient (Patient 2), infection parameters were within normal limits, but redness and fever were present at the wound site; the SUV_{max} value in this patient was 5.17 (Table 1). In 2 of 15 patients (Patients 4 and 12), no abnormal FDG uptake was detected on PET/CT (Table 1). While infection parameters were high in one of these patients and normal in the other, both patients presented with fever and discharge from the catheter. The involvement was limited to the driveline in 10 patients, while in three patients (Patients 6, 9, and 15), involvement was detected in both the pump and driveline (Table 1). The average SUV_{max} value in the 10 patients with driveline involvement was 6.67 (range: 2.76–15.11). In the three patients with both pump and driveline involvement, the average SUV_{max} value was 11.28 (range: 7.52–16.20) (Table 1).

Patients' Clinical Data

Before the PET/CT examination, the presence of infection was assessed based on clinical and laboratory findings. C-reactive protein (CRP) or white blood cell (WBC) levels were high in 13 patients (87%). Clinical findings such as fever, wound discharge, and skin redness at the driveline exit site were observed in all 15 patients (100%) (Table 1). In the microbiological evaluation of 12 patients with positive PET/CT findings, *Staphylococcus aureus* and *Pseudomonas aeruginosa* were identified as pathogens at the driveline exit site (Table 1). Clinical and laboratory results supported the presence of LVAD infection in these 12 patients with positive PET/CT findings (Table 1). In one patient with positive PET/CT involvement (Patient 2), laboratory results were normal and no bacterial growth was observed in culture. The laboratory values of the patients with no positive uptake on PET/CT (Patients 4 and 12) were normal, and there was no growth

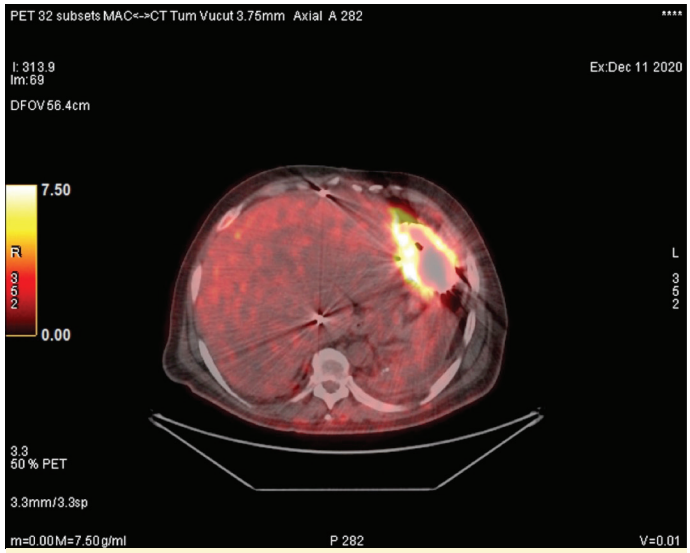

Figure 1. Focal, severe FDG uptake in favor of pump infection.

in the cultures of either patient (Table 1). PET/CT scans were performed in these patients due to clinical suspicion of infection (catheter exit site discharge).

Patient Treatment Methods

In the three patients with both LVAD pump (Figure 1) and driveline (Figure 2) involvement on PET/CT (Patients 6, 9, and 15), all components of the device were replaced. Nine patients with driveline involvement on PET/CT were treated with antibiotic therapy. After treatment, clinical and laboratory values returned

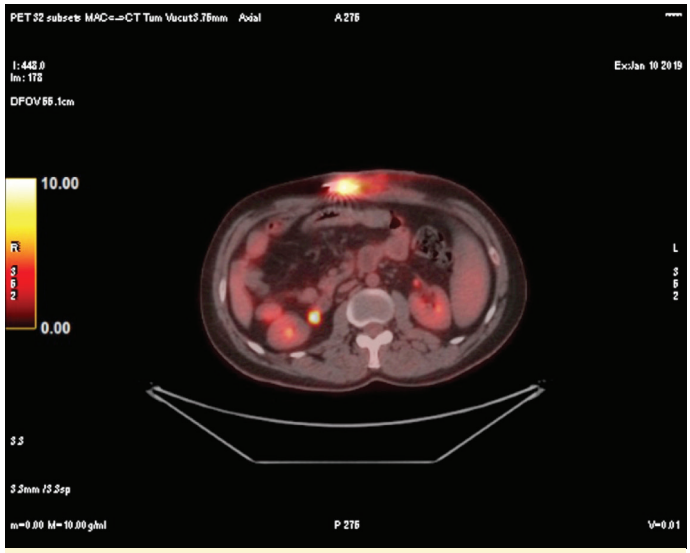

Figure 2. Focal, severe FDG uptake in favor of driveline infection.

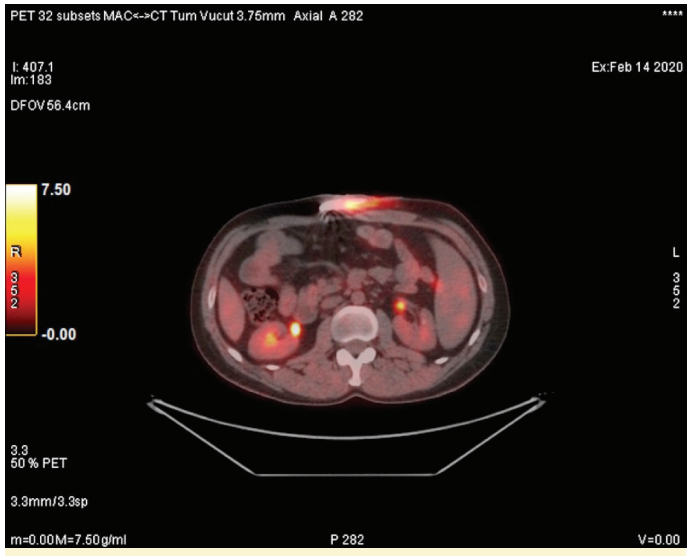

Figure 3. Relatively mild, linear false-positive FDG uptake in the driveline.

to normal, and no growth was observed in follow-up cultures. These patients were considered responsive to treatment. In one patient (Figure 3), positive uptake was detected on PET/CT, but no growth was found in microbiological cultures. In two patients with no PET/CT uptake, wound care and dressing were performed.

Statistical Values of PET/CT Findings

No statistical software was used in this study. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated manually using a confusion matrix created in Microsoft Word (Microsoft Corp., Redmond, WA, USA). These metrics were derived from the raw data obtained in the study. Among the 15 LVAD carriers evaluated, the diagnostic performance of F18 FDG PET/CT or detecting device infection was calculated as follows: sensitivity 100%, specificity 66%, PPV 92%, NPV 100%.

Discussion

According to the Infectious Diseases Council of the International Society for Heart and Lung Transplantation (ISHLT), ventricular assist device (VAD)-associated infections are classified into three categories: VAD-specific (e.g., pump pocket, cannula, driveline), VAD-associated (e.g., mediastinitis, bacteremia secondary to VAD), and non-VAD infections.[7] In our study, VAD-specific and VAD-associated infections were examined.

Early detection of infection in patients with LVADs and the specific localization of the infection are very important for patient management. As demonstrated in our study, F18 FDG PET/CT is suitable for this purpose as a test with high sensitivity and high positive and negative predictive values. If the infection has spread to central components such as the pump in LVAD carriers, device replacement is preferred. In peripheral infections such as driveline infections, medical treatment is the appropriate approach.[8]

In our study, device replacement was required in three patients in whom pump infection was detected. These LVAD exchanges were not performed solely on the basis of PET/CT findings but in conjunction with clinical, microbiological, and surgical evaluations. LVAD exchange is a high-risk procedure, and in our study, all three patients required device replacement due to progressive infection confirmed microbiologically. All patients were in good condition after replacement. Transplantation was considered but was not immediately feasible due to donor shortage and patient condition. These results are consistent with previous reports highlighting the complexity and risks associated with LVAD exchange procedures.[9]

We also prepared a flowchart (Figure 4) summarizing our institutional approach for the diagnosis and management of LVAD infections, demonstrating the role of FDG PET/CT alongside clinical, microbiological, and imaging modalities.

Moreover, detection of pump infection may be difficult with other diagnostic methods. Noninvasive detection of pump infection using F18 FDG PET/CT can protect patients from invasive procedures that require puncture.[10] F18 FDG PET/CT imaging carries an increased risk of foreign body reaction in different components, and FDG uptake in these areas can also be observed. Various semiquantitative cutoff SUV_{max} values have been determined to distinguish these involvements from true infectious involvement. In previous studies, threshold values of 4.5 for the driveline exit site, 3.1 for the subcutaneous driveline, and 5.7 for the pump have been reported.[11,12]

Since there was only one false-positive inflammatory involvement in our study, we could not determine a specific SUV_{max} threshold. However, while the average SUV_{max} value in our true-positive patients was 7.95, the SUV_{max} value in the false-positive patient was 5.17. These findings further demonstrate that inflammatory involvements are generally less focal and intense than infectious involvements. Therefore, as observed in our study, the presence of inflammatory involvement may reduce the sensitivity of F18 FDG PET/CT.

In addition, inflammatory involvements are linear and homogeneous. Although this pattern is helpful for qualitatively distinguishing inflammatory from infectious involvement, it

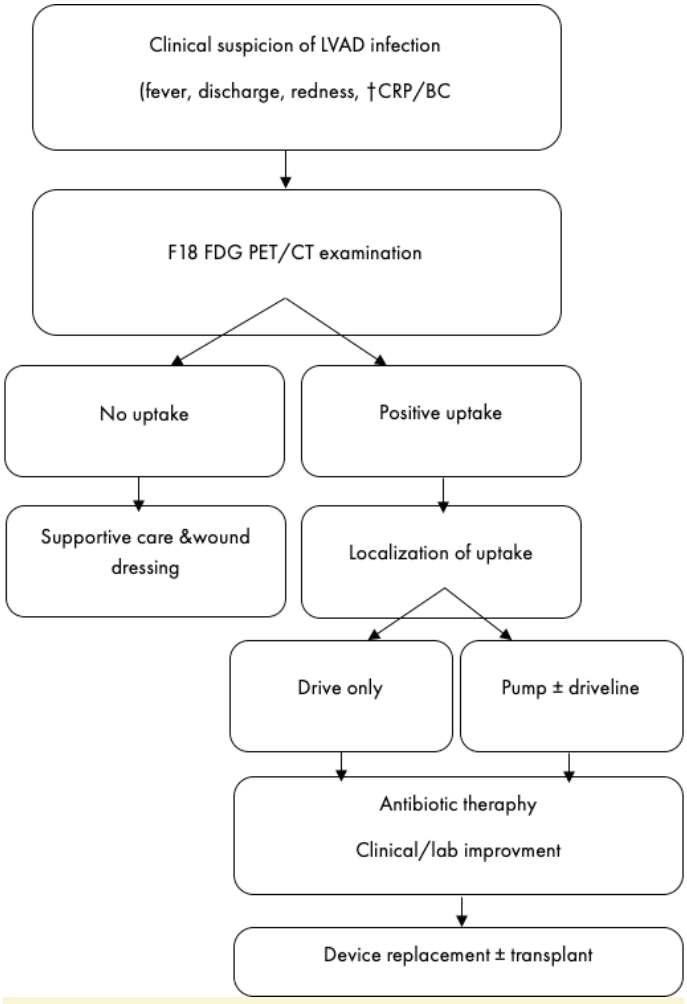

Figure 4. Flowchart: Management of LVAD Infections with F18 FDG-PET/CT.

Figure 5. Slightly, linear FDG uptake in the driveline's proximal part and focal, severe distal. FDG uptake compatible with infection.

can sometimes be difficult to differentiate between the two.[13] For example, in our study, one patient (Patient 11) showed linear, mildly increased FDG uptake in the proximal part of the driveline and focal, intense FDG uptake in the distal part of the driveline (Figure 5). The patient was interpreted as PET-positive due to focal, intense involvement in the distal part, and subsequent microbiological culture demonstrated bacterial growth. Prospective studies with larger patient cohorts are needed to determine the cutoff SUV_{max} value that can be used semiquantitatively to differentiate infection from inflammatory involvement.

In addition to FDG-PET/CT, other complementary modalities such as echocardiography, conventional CT, magnetic resonance imaging (MRI), and microbiological cultures remain essential for the diagnosis and follow-up of LVAD infections. PET/CT adds particular value by providing early localization and metabolic characterization of the infection focus, which is often challenging with standard techniques.[4]

Conclusion

In conclusion, imaging with F18 FDG PET/CT is a highly sensitive modality with high positive and negative predictive values for the detection, localization, and characterization of different patterns of LVAD infections according to the causative pathogens, clinical scenarios, and distribution. The primary use of this imaging technique in LVAD infection can assist clinicians in management decisions and help identify patients who may require surgical intervention, device replacement, or emergency heart transplantation.

Ethics Committee Approval: Ethics committee approval was obtained from Ümraniye Training and Research Hospital Scientific Research Ethics Committee (Approval Number: B.10.1.TKH.4.34.H.GP.0.01/221, Date: 10.07.2025).

Informed Consent: Written informed consent was obtained from all participants prior to their inclusion in the study.

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