JACC: CARDIOVASCULAR IMAGING VOL. 6, NO. 9, 2013

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC. http://dx.doi.org/10.1016/j.jcmg.2013.07.004

iPIX

IMAGING VIGNETTE

CT Angiography and ^{18}F-FDG-PET Fusion Imaging for Prosthetic Heart Valve Endocarditis

Wilco Tanis, MD,* Asbjørn Scholtens, MD,† Jesse Habets, MD, PhD,‡
Renee B. A. van den Brink, MD, PhD,§ Lex A. van Herwerden, MD, PhD,||
Steven A. J. Chamuleau, MD, PhD,* Ricardo P. J. Budde, MD, PhD‡

IN PROSTHETIC HEART VALVE (PHV) ENDOCARDITIS, transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) may occasionally fail to recognize vegetations and periannular extensions (abscesses/mycotic aneurysms) due to acoustic shadowing by the metal PHV ring (1). In approximately 50% of cases, PHV endocarditis is complicated by periannular extensions, which is an indication for urgent surgery in order to improve survival (1). Additional imaging with retrospectively electrocardiogram-gated computed tomography angiography (CTA) or ^{18}F-fluorodeoxyglucose positron emission tomography including low-dose computed tomography (FDG-PET/CT) and a low-carbohydrate diet improve diagnostic accuracy. However, PHV endocarditis may still be missed by both individual diagnostic tools (2,3). Combining or even fusing both diagnostic tools results in state-of-the-art high-resolution anatomic and metabolic imaging of the PHV and its surrounding anatomy, which may be the desired imaging strategy in patients with suspicion of PHV endocarditis. Furthermore, whole-body FDG-PET/CT can detect primary foci or metastatic infections in PHV endocarditis, which may have therapeutic consequences as well.

FDG-PET/CT and CTA imaging independently are promising tools to correctly diagnose PHV endocarditis in patients with a negative or inconclusive routine work-up with TTE and TEE (2,3). FDG-PET with localizing lowdose CT for attenuation correction is able to detect periannular extensions of PHV endocarditis in which standardized uptake value (SUV) ratios may be of additional help. All presented and surgically confirmed cases with periannular extensions had a SUV ratio of more than 3.5 and a SUV maximum of more than 6.8. As reported in the literature and shown in this case series, FDG-PET alone may miss highly mobile vegetations, probably due to its low spatial resolution. Furthermore, the low-dose CT that comes with FDG-PET is not electrocardiogram gated nor contrast enhanced, and therefore unable to detect vegetations. For this reason, an additional CTA may be of complementary value to detect, not only vegetations, but also anatomic aortic root abnormalities and coronary artery obstructions. CTA

From the *Department of Cardiology, University Medical Center Utrecht, Utrecht, the Netherlands; †Department of Nuclear Medicine, University Medical Center Utrecht, Utrecht, the Netherlands; ‡Department of Radiology, University Medical Center Utrecht, Utrecht, the Netherlands; §Department of Cardiology, Academic Medical Center, Amsterdam, the Netherlands; and the ||Department of Cardiothoracic Surgery, University Medical Center Utrecht, Utrecht, the Netherlands. This work was supported by a grant from the Dutch Heart Foundation (NHS 2009B014). Dr. van Herwerden has been a consultant to and on the review board for St. Jude Medical, for which he received <$10,000. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

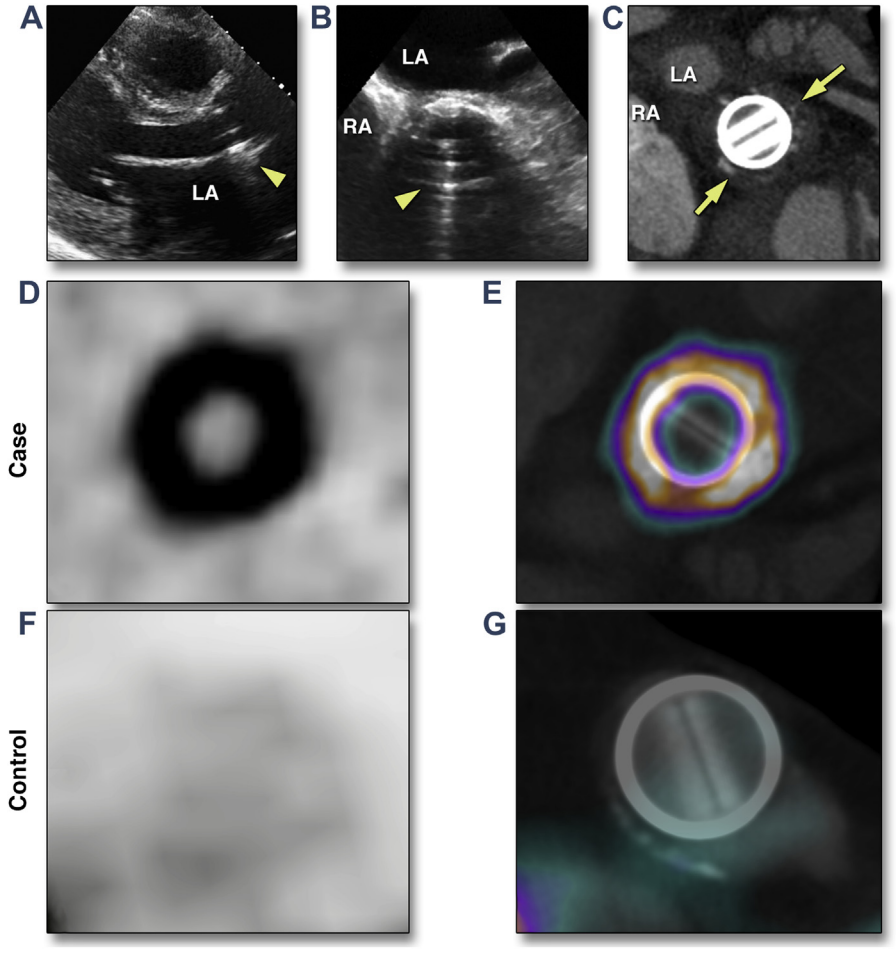

Figure 1. PHV Endocarditis With Periannular Extension Missed by Echocardiography, but Correctly Detected by CTA and FDG-PET

A patient with an aortic 23 mm Carbomedics (Sorin S.p.A., Milan, Italy) mechanical prosthetic heart valve (PHV) including a Bentall tube implanted 7 years previously and multiple blood cultures positive for *Staphylococcus aureus*. **(A)** The diastolic phase of the parasternal long-axis transthoracic echocardiography (TTE) and **(B)** the systolic short-axis transesophageal echocardiography (TEE) are shown. **Arrowheads** indicate acoustic shadowing by the PHV. **(C)** An additional computed tomography angiography (CTA) was performed that detected aortic wall thickening (8 mm, **arrows**) around the PHV ring. **(D)** For confirmation purposes, an additional 18F-fluorodeoxyglucose positron emission tomography/low-dose computed tomography (FDG-PET) scan was performed, which showed severe FDG uptake at the level of the aortic PHV. **(E)** FDG-PET after fusion with CTA is shown. No baseline uptake values for PHV are reported in the literature. Panels **F** and **G**, however, show scans by FDG-PET alone **(F)** and fused with CTA **(G)** of a pulmonic PHV without endocarditis (control). Quantitative measurement of the standardized uptake value (SUV) ratios (defined as the maximum SUV value adjacent to the PHV ring divided by the mean SUV value of the blood pool in the descending aorta) may be of additional help for the detection of periannular extensions. In our hospital database, we found 4 PHV without endocarditis (controls), including normal CTA and TEE, who all had a SUV ratio below 2.2. In the presented control and case, SUV ratios were 1.4 (2.18:1.60) and 5.9 (9.44:1.60), respectively. LA = left atrium; RA = right atrium.

may sometimes replace invasive coronary angiography, which is desired in aortic PHV endocarditis with vegetations. In conclusion, in addition to echocardiography, the independent, combined, or even fused use of FDG-PET/CT and CTA may have complementary beneficial value in patients with PHV endocarditis and may guide therapeutic strategies (Figs. 1 to 7).

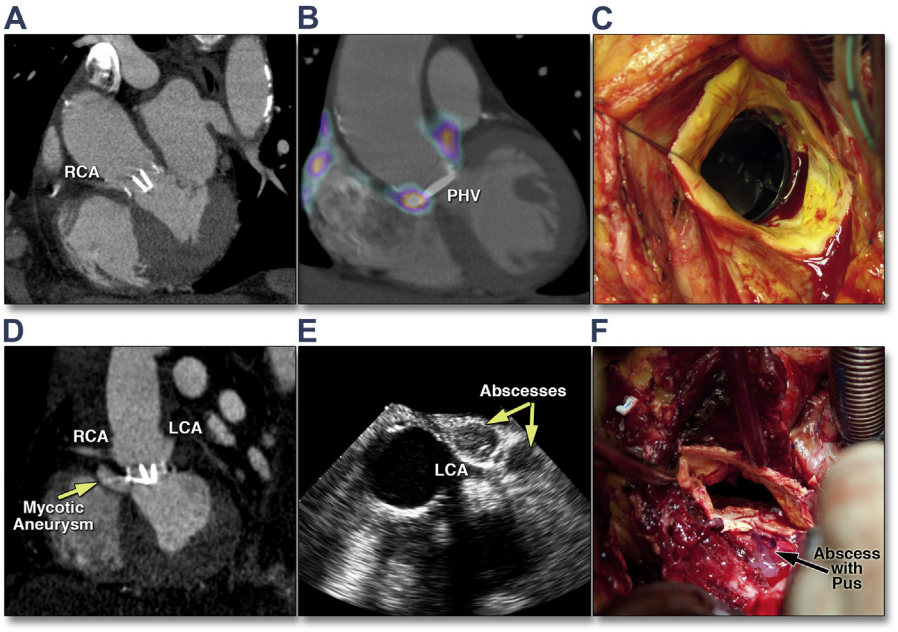

Figure 2. Periannular Extension of PHV Endocarditis Initially Missed by TTE/TEE/CTA but Correctly Detected by FDG-PET

A patient with a bileaflet mechanical PHV in the aortic position for 20 years presented with fever and, subsequently, 4 consecutive blood cultures positive for *S. aureus*. Despite a high clinical suspicion for endocarditis, TTE/TEE, as well as CTA **(A)**, were unremarkable. Modified Duke criteria were not fulfilled. However, FDG-PET/low-dose CT revealed high uptake around the aortic PHV, with a SUV ratio of 4.2 (6.88:1.63). After fusion with cardiac CTA (Online Video 1), the high uptake was demonstrated around the PHV near the proximal right coronary artery (RCA) and left coronary artery (LCA) **(B)**. Because Q6 of persistent fever despite adequate antibiotic treatment, it was decided to perform surgical inspection 6 days after presentation. In contrast to the FDG-PET/CT findings, surgical inspection did not reveal macroscopic PHV abnormalities **(C)**, although no inspection under the ring was performed, nor were biopsies taken from this area. Eight days after this surgery, additional CTA and TEE were performed because of stroke and persistent fever. Now, CTA revealed a mycotic aneurysm beneath the RCA origin **(D)**, and TEE (**E**, Online Video 2) showed 2 abscesses around the LCA, all confirmed by urgent reoperation. **(F)** shows the aortic root after explantation of the PHV, with pus in the LCA region **(arrow)**. Retrospectively, only FDG-PET/CT detected these findings at a very early stage. After fusion with CTA, the involvement of the coronary arteries in the infected area was imaged, which is also important for the pre-operative surgical strategy. Moreover, because CTA was performed, no invasive coronary angiography was needed anymore. LCA = left coronary artery; RCA = right coronary artery; other abbreviations as in Figure 1.

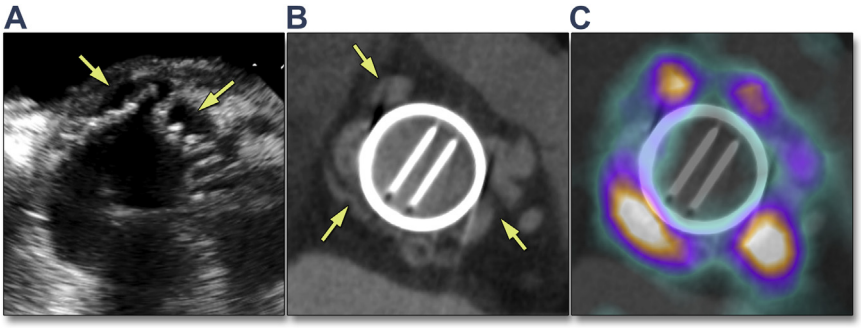

Figure 3. Additional Value of CTA and FDG-PET for the Confirmation of PHV Endocarditis With Periannular Extension

An asymptomatic patient underwent a routine TTE 6 weeks after an uncomplicated mechanical bileaflet aortic PHV (St. Jude Medical) implantation. TTE revealed the suggestion of aortic root abnormalities. Blood cultures remained negative, and the C-reactive protein (CRP) level was only 68 mg/l. TEE (**A**, short-axis view) and CTA (**B**, rotated in the same view as the TEE view) revealed no vegetations, but irregular blood/contrast-filled cavities at the level of the aortic root **(arrows)**. This is most likely compatible with multiple mycotic aneurysms, but could theoretically also be noninfected post-operative root abnormalities. Furthermore, the modified Duke criteria were not fulfilled, and CRP levels decreased spontaneously. A follow-up FDG-PET/CT scan showed high uptake around the PHV with a SUV ratio of 3.8 (7.17:1.91), which convinced the surgeon of the need for a high-risk re-operation. Fusion of FDG-PET with CTA demonstrated uptake in most of the aortic root abnormalities **(C)**. It was decided to re-operate; surgery revealed multiple mycotic aneurysms, confirmed by pathological examination. This case shows that confirmation of infection of the aortic root is possible by addition of FDG-PET and CTA to echocardiography. Abbreviations as in Figure 1.

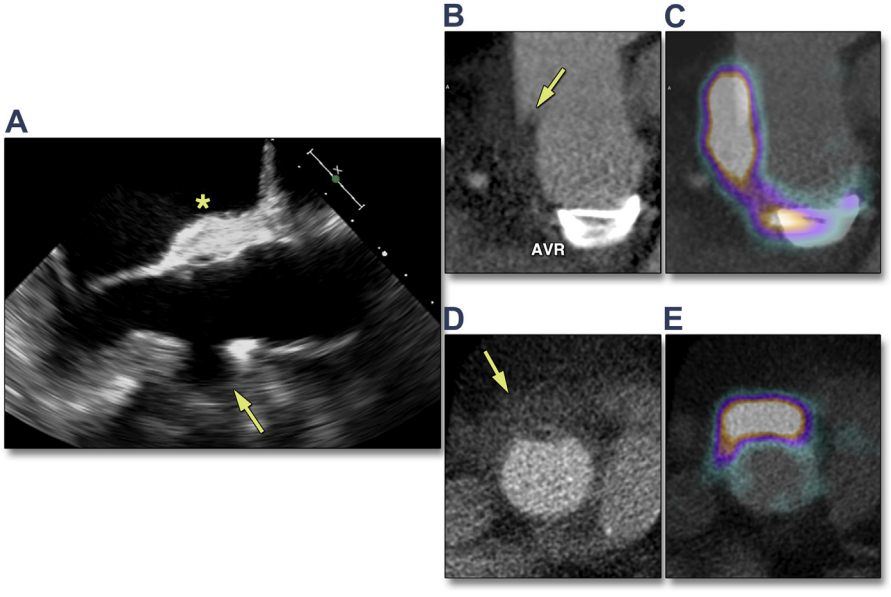

Figure 4. Diagnostic Dilemma With Inconclusive TTE/TEE in the Context of High Suspicion of PHV Endocarditis

A patient with a Bentall tube and St. Jude mechanical aortic PHV (St. Jude Medical, St. Paul, Minnesota) implanted 26 months previously presented with high fever and 3 consecutive blood cultures positive for *Actinobaccilus*. TEE (**A**, 120 TEE view) was interpreted as aspecific thickening **(asterisk)** of the posterior aortic wall because the outpatient clinic TTEs before the fever already showed this thickening. Modified Duke criteria were not fulfilled. The arrow points to the anterior side, where TEE imaging was hampered by acoustic shadowing. By contrast, CTA revealed, not only a vegetation on the anterior side of the Bentall tube **(B, arrow)**, but also thickening/fatty infiltration of the anterior side of the Bentall prosthesis and PHV ring **(D, arrow)**. **(C and E)** FDG-PET/CT corroborated this observation by detecting high uptake only around the anterior side of the Bentall tube and PHV ring, with a SUV ratio of 8.1 (14.96:1.85). Complicated infection of the Bentall prosthesis was diagnosed by CTA and FDG-PET/CT independently and correspondingly after fusion, confirmed by surgical inspection and pathological examination. This case shows that in contrast to echocardiography, CTA detected the vegetation and periannular extension. FDG-PET was of additional clinical value in confirming the periannular extension on the anterior side of the Bentall tube. Abbreviations as in Figure 1.

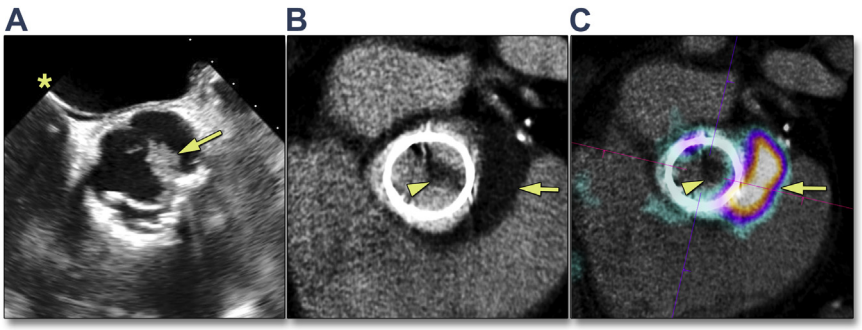

Figure 5. Combined CTA and FDG/PET Imaging Detects Both Vegetations and Periannular Extensions

A patient with a biological PHV in the aortic position for 10 months presented with fever and 4 consecutive blood cultures positive for *S. aureus*. **(A)** the short-axis TEE view shows a large vegetation (1.7 cm in length, arrow). No periannular extensions were observed. The modified Duke criteria were fulfilled. **(B)** 2 days later, CTA (rotated in the same view as the short-axis TEE view) detected, not only the vegetation **(arrowhead)**, but also a thickened aortic wall in the former right to left coronary cusp **(arrow)**, indicating a periannular extension of PHV endocarditis, which is an indication for urgent reoperation. Retrospectively, imaging of this area by TEE **(A)** was hampered by acoustic shadowing by the PHV. **(C)** FDG-PET/CT (low dose) alone missed the large vegetation (the arrowhead points to absent FDG uptake in the large vegetation), but detected high uptake around the PHV, with a SUV ratio of 3.5 (7.43:2.11). At urgent reoperation, a large vegetation and periannular extension around the former left coronary cusp was observed and confirmed by pathological examination. This case shows that periannular extensions can be missed by echocardiography, but correctly diagnosed by FDG-PET/low-dose CT and CTA independently and after fusion. However, vegetations can be missed by FDG-PET/low-dose CT alone. CT = computed tomography; other abbreviations as in Figure 1.

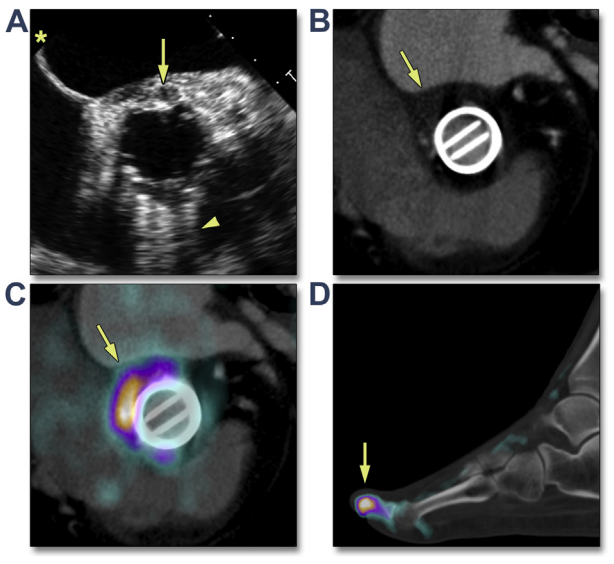

Figure 6. Extracardiac Focus in Proven PHV Endocarditis Detected by Whole-Body FDG-PET/Low-Dose CT

A patient with a bileaflet mechanical PHV in the aortic position implanted 13 years earlier presented with fever and 4 consecutive blood cultures positive for *S. aureus*. Short-axis TEE revealed no vegetations but did show a thickened wall without color Doppler flow in the former noncoronary cusp region. This was suggestive of an abscess **(A, arrow)**. **(B)** CTA confirmed the TEE findings, showing a thickened aortic root **(arrow)** without significant contrast extravasations and no vegetations. FDG-PET/CT alone detected high uptake around the PHV, with a SUV ratio of 4.1 (8.42:2.07). After fusion of the CTA with FDG-PET **(C)**, the thickened aortic root showed high metabolic activity **(arrow)**, confirming abscess formation. The primary focus was most likely an infection of the fourth toe. This patient was already treated by the surgeon for this infection, which was considered to be only a superficial infection caused by delayed healing secondary to known peripheral artery disease. However, whole-body FDG-PET/CT showed the fourth toe to have osteomyelitis (**D**, **arrow**), requiring a guillotine resection before a cardiac reoperation was performed. Subsequent PHV reoperation revealed periannular extension of PHV endocarditis (no vegetations), confirmed by pathological examination. This case shows that even if echocardiography correctly diagnoses PHV endocarditis with periannular extension, additional whole-body FDG-PET/CT has additional value with therapeutic consequences. Abbreviations as in Figures 1 and 5.

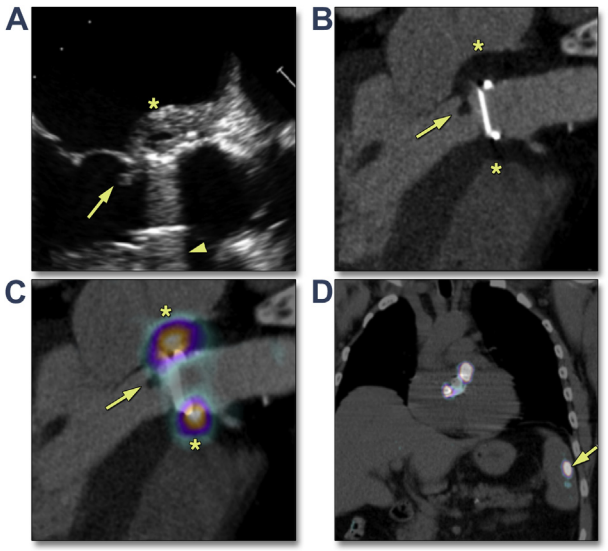

Figure 7. Metastatic Infection in PHV Endocarditis Detected by Whole-Body FDG-PET/Low-Dose CT

A patient with a bileaflet mechanical PHV in the aortic position for 6 years presented with fever and 7 consecutive blood cultures positive for *S. pneumoniae*. **(A)** 120 TEE view showed a vegetation **(arrow)** and thickened wall **(asterisk)** without color Doppler flow in the former noncoronary cusp region, suggestive of an abscess. Former right coronary cusp imaging is hampered by acoustic shadowing **(arrowhead)**. Modified Duke criteria were fulfilled. **(B)** CTA confirmed the vegetation **(arrow)** but also showed thickened aortic walls, not only near the former noncoronary cusp, but also near the former right coronary cusp **(asterisks)**. **(C)** CTA fused with FDG-PET confirmed abscess formation near the former right and noncoronary cusps **(asterisks)**. The SUV ratio was 5.2 (9.74:1.88) at a CRP level of 77 mg/l. The vegetation **(arrow)** did not show FDG uptake, probably due to the large amount of motion of the valve leaflets and vegetations resulting in blurring of the PET signal beyond the point of detectability. Other contributing causes of missing vegetations may be the low spatial resolution of PET imaging, the background activity of the blood pool, and/or direct exposure of vegetations to antibiotics in the bloodstream, which make them more prone to be sterilized. Additionally, whole-body FDG-PET/CT showed a metastatic infection in the spleen **(D, arrow)**, in this case, an abscess requiring percutaneous drainage. Subsequent cardiac surgery and pathological examination confirmed the vegetation and widespread periannular extension, requiring homograft implantation. Although Duke criteria were already fulfilled in this patient before addition of CTA and FDG-PET/CT, the additional imaging was useful because the periannular extension was more extensive than TEE suggested. This guided the pre-operative strategy in that a homograft needed to be ordered and a metastatic infection was diagnosed that necessitated additional therapy before re-operation of the PHV. Abbreviations as in Figure 1.

Address for correspondence: Dr. Wilco Tanis, University Medical Center Utrecht, Heidelberglaan 100, 3508 GA Utrecht, the Netherlands. *E-mail: w.tanis-2@umcutrecht.nl.*

REFERENCES

1. Hill EE, Herijgers P, Claus P, Vanderschueren S, Peetermans WE, Herregods MC. Abscess in infective endocarditis: the value of transesophageal echocardiography and outcome: a 5-year study. Am Heart J 2007;154:923–8.
2. Fagman E, Perrotta S, Bech-Hanssen O, et al. ECG-gated computed tomography: a new role for patients with suspected aortic prosthetic valve endocarditis. Eur Radiol 2012;22:2407–14.
3. 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;61:2374–82.

APPENDIX

For supplementary videos, please see the online version of this article.