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Multimodal Imaging in *Mycobacterium Chimaera* Cardiovascular Infections: The Mayo Clinic Experience

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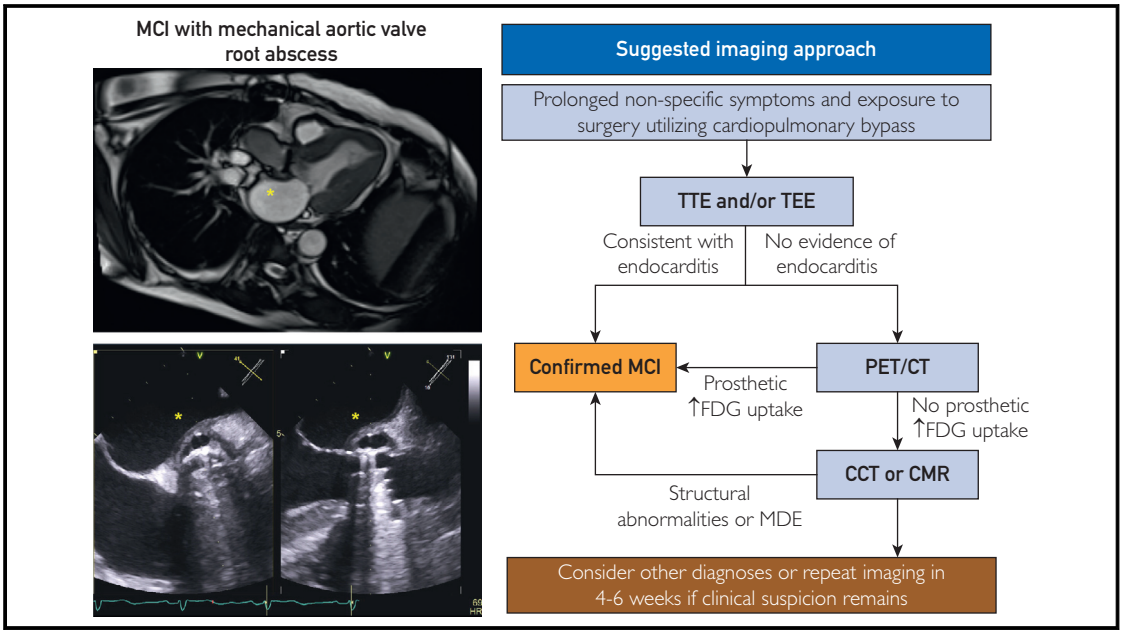
GRAPHICAL ABSTRACT



Abstract

Objective: To review the salient features of multimodality cardiovascular imaging in patients with disseminated *Mycobacterium chimaera* (MC) infections after exposure to contaminated heater-cooler units during cardiopulmonary bypass.

Patients and Methods: Twelve patients with confirmed MC infection were retrospectively identified after a review from January 1, 2010, to April 30, 2021. The electronic medical records were examined with a focus on transthoracic echocardiography, transesophageal echocardiography, cardiac computed tomography (CT), cardiac magnetic resonance imaging, and positron emission tomography-CT.

Results: Three (27.3%) patients had diagnostic findings of endocarditis on transthoracic echocardiography, with most patients having nonspecific abnormalities including elevated prosthetic valve gradients or prosthetic leaflet thickening. Transesophageal echocardiography identified 4 (36.7%) patients with vegetations and 3 (27.3%) with aortic root abscess or pseudoaneurysm, with more common findings such as mild aortic root or prosthetic leaflet thickening. Six (50%) patients underwent cardiac CT imaging, which found aortic root pseudoaneurysms or abscesses, prosthetic ring dehiscence, and leaflet thickening. Three (25%) patients underwent cardiac magnetic resonance imaging demonstrating prosthetic valve vegetations, leaflet thickening, and abnormal myocardial delayed enhancement in a noncoronary

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distribution, suggesting myocarditis. Ten (83%) patients underwent positron emission tomography-CT, 4 (40%) had an abnormal fluorodeoxyglucose uptake around the cardiac prosthetic material, and 7 (70%) had a fluorodeoxyglucose uptake in other organs, suggesting concomitant multiorgan involvement.

Conclusion: Multimodality cardiovascular imaging is central to the management of patients with disseminated MC and can help establish a preliminary diagnosis while awaiting confirmatory microbiological data, potentially reducing the time to diagnosis. Imaging findings are subtle and atypical, not always meeting classically modified Duke's criteria for infectious endocarditis. Clinicians should have a high index of suspicion for the disease and a low threshold for repeat imaging when initial testing is equivocal.

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Mycobacterium chimaera (MC) is a fastidious, nontuberculous mycobacterium that has been implicated in multiple outbreaks of disseminated infections after exposure to contaminated heater-cooler devices during cardiopulmonary bypass.[1] The clinical presentation is nonspecific[2,3] and necessitates a high index of suspicion for timely diagnosis. Even when MC is suspected, the prolonged incubation period and technical complexities of species-level identification lead to a delayed diagnosis. Multimodality cardiovascular imaging can help identify imaging characteristics, and when combined with a clinical history of previous exposure to cardiopulmonary bypass and classic symptoms, it can help establish a presumptive diagnosis and prevent delays in empiric treatment. Given the lack of data on the yield of multimodality imaging, we reviewed our institutional experience in the management of disseminated MC (Graphical Abstract) and present the results here.

PATIENTS AND METHODS

We retrospectively identified patients with a diagnosis of MC endocarditis at our institution from January 1, 2010, to April 30, 2021. All patients met the diagnostic criteria set forth by Hasse et al[4] including the presence of clinical symptoms or signs consistent with MC infection, previous exposure to cardiopulmonary bypass, and microbiological confirmation of MC. The study was approved by the Mayo Clinic institution review board (#18-004-096). Patient demographic characteristics, clinical or surgical characteristics, laboratory data, and microbiology data (including blood or tissue cultures and molecular testing) were abstracted. Multimodality imaging data, such as transthoracic and transesophageal echocardiography (TTE and TEE), cardiac computed tomography, cardiac magnetic resonance imaging (MRI), and positron emission tomography-computed tomography (PET-CT) data, were reviewed.

Transthoracic and Transesophageal Echocardiography

Comprehensive TTE and TEE were performed according to the guidelines set forth by the American Society of Echocardiography.[5,6] Special attention was paid toward assessment of prosthetic valves, including 2-dimensional, color flow, and Doppler imaging to identify and quantify periprosthetic or prosthetic regurgitation, measure prosthetic valve gradients, assess for thickening of aortic root or prosthetic graft material, or the presence of frank abscess or pseudoaneurysm. Imaging tests performed at other facilities were also recorded. Where possible, the corresponding images were requested and reviewed by a dedicated imaging specialist from our institution. In addition, all images were reviewed independently offline by the authors (S.V., N.Y.T., N.S.A., and C.E.B.).

Cardiac Computed Tomography

Cardiac computed tomography with 3D image postprocessing was performed with iodinated intravenous contrast. Retrospective electrocardiogram triggering was used for image acquisition to provide a comprehensive, 4-dimensional assessment of valvular function. Noncontrast acquisitions were also obtained to aid in the detection of calcifications and surgical material. A delayed phase (40-80 seconds) flash gated CT angiographic image acquisition was performed

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to aid in the evaluation of a potential intracardiac thrombus or abscess.

Cardiac MRI

Cardiac MRI was performed on 1.5-T General Electric Medical Systems or Siemens scanners using standardized institutional protocols and electrocardiographic triggering. All patients underwent imaging with gadolinium-based contrast enhancement, unless contraindicated. Conventional sequences were used for steady state free precession cine imaging (Fast Imaging Employing Steady-State Acquisition or True Fast Imaging with Steady State Precession) in 4-chamber, 2-chamber, and short axis views, double and triple inversion recovery in dark blood imaging, perfusion sequences, cine inversion recovery, and delayed enhancement sequences. Late gadolinium enhancement imaging was performed ∼8-10 minutes after contrast administration. Circle cardiovascular imaging (cvi42) postprocessing software was used for measurement of cardiac volumes, function, and mass with artificial intelligence guided auto contour detection and manual correction where necessary. The MRI images were evaluated with a special focus on valvular pathologies, such as masses, vegetations, stenosis, or regurgitation notable on cine imaging sequences, and abnormal enhancement of valves, prosthetic material, major vasculature, myocardium, or pericardium on delayed enhancement sequences.

Positron Emission Tomography-Computed Tomography

Before imaging, patients received a high-fat, low-carbohydrate diet to suppress physiologic myocardial glucose utilization and thereby improve the sensitivity of detecting pathological fluorodeoxyglucose (FDG) uptake to suggest an infectious or inflammatory process. Fluoro-18 (^{18}F)-FDG) was injected by weight-based dosing after a point-of-care glucose level check. Image acquisition was performed 45-60 minutes post-injection. The images were then analyzed for abnormal FDG uptake anywhere in the body, with special attention to the prosthetic valve or graft sites.

Statistical Analyses

Continuous data were represented as median values with range. Categorical data were represented as counts (%).

RESULTS

Twelve cases of MC endocarditis were identified. All were associated with a previous history of cardiovascular surgery. All patients had a history of aortic valve replacement, except one who had an aortic aneurysm graft repair alone. Other concomitant surgeries include coronary artery bypass grafting (16.7%), aortic root replacement (8.3%), ascending aorta graft repair or replacement (16.7%), and left atrial appendage occlusion (8.3%).

Baseline characteristics and clinical variables are summarized in Table 1. Ten cases (83.3%) were male, with a mean age at

TABLE 1. Baseline Characteristics and Clinical Presentations

Variable	(N=12)
Mean age at presentation ± SD	64.8±5.6
Male sex (%)	10 (83.3)
Mean age at surgery (SD), y	64.7±5.5
Cardiovascular surgical intervention, n(%)	
AVR alone	5 (41.7)
AVR + CABG	2 (16.7)
AGR alone	1 (8.3)
Composite aortic valve graft	1 (8.3)
AVR + AGR	2 (16.7)
AVR + AAC	1 (8.3)
Median duration from surgery to symptom onset (range), mo	25 (13-73)
Median duration from presentation to diagnosis (range), mo	6.5 (1-13)
Presenting symptoms, n (%)	
Weight loss	8 (66.7)
Fatigue	7 (58.3)
Fever	5 (41.7)
Night sweats	4 (33.3)
Altered mental status	3 (25.0)
Anorexia	2 (16.7)
Disequilibrium	2 (16.7)
Heart failure	1 (8.3)
Cough	1 (8.3)
Diplopia	1 (8.3)
Other organ manifestations	
Constitutional (%)	12 (100)
Hematologic (%)	8 (66.7)
Renal (%)	6 (50)
Ocular (%)	10 (83.3)
Neurologic (%)	6 (50)

Abbreviations: AAC, atrial appendage closure; AGR, aortic graft replacement; AVR, aortic valve replacement; CABG, coronary artery bypass grafting; SD, standard deviation.

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diagnosis of 64.8±5.6 years. The median time to symptom development after surgery was 25 months (range 12-73 months), and the median time to diagnosis after symptom development was 6.5 months (range 1-13 months). The most common presentation was with constitutional symptoms, such as weight loss (66.7%), fatigue (58.3%), fever (41.7%), and night sweats (33.3%). Hematological involvement was common (66.7%), in the form of splenomegaly (91.7%) on imaging, anemia (66.7%), and pancytopenia (41.7%). One patient also had manifestations of hemophagocytic lymphohistiocytosis.

Common laboratory abnormalities included transaminitis (50.0%) and renal dysfunction (33.3%), which prompted liver and kidney biopsies. Pathology from bone marrow (50%), kidneys (16.7%), skin (8.3%), duodenum (8.3%), and liver (8.3%) reported noncaseating granulomas. Funduscopic examination revealed chorioretinal lesions in 10 of the 11 (83.3%) patients who underwent ophthalmological evaluation.

Eleven (91.7%) patients had positive mycobacterial blood cultures. The remaining 1 patient was diagnosed postoperatively after undergoing repeat cardiovascular surgery, given the high index of suspicion for MC, with subsequent positive mycobacterial culture from surgical tissue specimens. Of the 11 patients with positive blood cultures, 3 also underwent a microbial cell-free deoxyribonucleic acid quantitative sequencing blood test (Karius), which resulted positive before the blood cultures. Mycobacterial cultures were also positive from specimens of bone marrow (16.7%), sputum (8.3%), and skin (8.3%) in the entire cohort.

Transthoracic Echocardiography

Eleven (92%) patients underwent TTE (Table 2). Although this was the initial imaging modality of choice for most patients, 2 patients (16.7%) had a TEE before the TTE, given the high index of suspicion for infective endocarditis. Of the 11 patients, only 3 (27.3%) had typical echocardiographic findings for infective endocarditis per modified Duke's criteria,[7] in the form of vegetations (9.1%), abscesses (18.2%), or the presence of a pseudoaneurysm (9.1%). One (9.1%) patient reported aortic root thickening concerning for infection. Three (27.3%) patients had elevated gradients across the prosthetic aortic valve in comparison to their previous baselines (Δ gradients of 24, 47, and 7 mm Hg). There was no evidence of moderate or greater than moderate prosthetic or periprosthetic regurgitation by TTE; 5 (45.5%) patients had trivial to mild regurgitation, and 6 (54.5%) had no regurgitation. Three (27.3%) patients had evidence of prosthetic leaflet thickening.

Transesophageal Echocardiography

Eleven patients (91.7%) underwent TEE (Table 2). Six (54.5%) patients found abnormal thickening of the aortic root. Five patients (45.5%) had evidence of thickened prosthetic valve leaflets. Four (36.7%) patients

TABLE 2. Summarized Findings on Transthoracic and Transesophageal Echocardiography[a]

Findings	TTE (n=11)	TEE (n=11)
Increased prosthetic valve gradient[b] (%)	3 (27.3)	N/A
Prosthetic or periprosthetic regurgitation (%)		
Absent	6 (54.5)	5 (45.5)
Trivial- Mild	5 (45.5)	6 (54.5)
Moderate or greater	0	1 (9.1)
Vegetations (%)	1 (9.1)	4 (36.7)
Prosthetic valve leaflet thickening (%)	3 (27.3)	5 (45.5)
Aortic root thickening (%)	1 (9.1)	6 (54.5)
Abscess/fistula (%)	2 (18.2)	3 (27.3)
Pseudoaneurysm (%)	1 (9.1)	1 (9.1)
No definite infection (%)	8 (72.7)	3 (27.3)

[a]Abbreviations: N/A, not applicable; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.
[b]Increased prosthetic valve gradient is defined as a ≥5 mm Hg increase in comparison to a previous baseline.

TABLE 3. Summarized Findings on PET-CT, Cardiac CT, and Cardiac MRI

PET-CT	Patients (N=10)
Noncardiovascular FDG uptake	7 (70%)
Aortic prosthesis/graft FDG uptake	4 (40%)
Periprosthetic fluid collection	2 (20%)
CCT	Patients (n=6)
Prosthetic leaflet thickening	2 (33.3%)
Pseudoaneurysm	2 (33.3%)
Aortic root thickening	1 (16.7%)
Periaortic abscess	2 (33.3%)
Prosthetic valvular dehiscence	1 (16.7%)
Prosthetic valve thrombosis	1 (16.7%)
CMR	Patients (n=3)
Vegetation	2 (66.7%)
Prosthetic leaflet thickening and enhancement	1 (33.3%)
Aortic root abscess	1 (33.3%)
Myocardial delayed enhancement in a nonischemic pattern	1 (33.3%)

Abbreviations: CT, computed tomography; CCT, cardiac computed tomography; CMR, cardiac magnetic resonance; FDG, fluorodeoxyglucose; MRI, magnetic resonance imaging; PET-CT, positron emission tomography-computed tomography.

had vegetations on the prosthetic valve. Three (27.3%) patients had abscesses associated with the aortic root or adjacent to prosthetic graft material. One (9.1%) patient had a pseudoaneurysm of the aortic root. Aortic prosthetic regurgitation was qualified as mild or less than mild in 10 patients, with only 1 (9.1%) patient reporting moderate regurgitation. Three (27.3%) patients had no definitive evidence of infection on TEE, despite positive microbiological cultures.

Cardiac Computed Tomography

Six (50%) patients underwent cardiac CT scans that were retrospectively gated to the electrocardiogram. The results are summarized in Table 3. Two (33.3%) patients found prosthetic leaflet thickening. Two (33.3%) patients had aortic root pseudoaneurysms, with one (16.7%) also showing evidence of dehiscence of an aortic prosthesis. One (16.7%) patient had evidence of aortic root thickening with a periaortic abscess. One (16.7%) patient had a filling defect associated with the prosthetic valve with a bland and smooth appearance, thought to be radiographically consistent with thrombus and later confirmed on surgical pathology. Figure 1 shows a representative case with a cardiac CT utilized.

Cardiac MRI

Three (25%) of the 12 patients underwent electrocardiogram-gated cardiac MRI with gadolinium enhancement. The results are summarized in Table 3. Two (66.7%) patients had evidence of vegetations on the aortic prosthesis. One (33.3%) patient had evidence of prosthetic valve leaflet thickening along with delayed gadolinium enhancement of the leaflets on postcontrast imaging. One (33.3%) had evidence of an aortic root abscess. One (33.3%) patient had evidence of delayed myocardial enhancement in a nonischemic pattern, suggestive of myocarditis in the setting of other evidence of infective endocarditis. Figure 2 includes representative cardiac magnetic resonance findings from a patient case.

Positron Emission Tomography-Computed Tomography

Ten (83%) patients underwent PET-CT imaging for evaluation of pathological FDG uptake to suggest infection, the results are summarized in Table 3. Notably, only 4 (40%) patients reported pathological FDG uptake in and around prosthetic material (prosthetic valves, aortic graft, and left atrial appendage occlusion clip). Seven (70%) patients had evidence of abnormal FDG uptake in other organs, such as the spleen, lungs, and bone marrow, suggestive of disseminated infection. Two (20%) patients also had evidence of abnormal uptake in mediastinal periprosthetic fluid collections. Supplemental Table (available online at http://www.mcpiqojournal.org) summarizes the patient-level data for the multimodal cardiovascular imaging studies presented in this report.

Clinical Outcomes

The median follow-up period was 13.5 months (range 0-60, 1 patient expired within 2 weeks of initial contact). Seven patients underwent redo cardiovascular surgery. One patient had a trial of prolonged antimicrobial therapy before undergoing surgery for a new prosthetic valve. Six had early surgical interventions; of those, 4 had no recurrence postoperatively and 2 had recurrence despite surgery (one of whom died of the disease 18 months after surgery). Four patients were

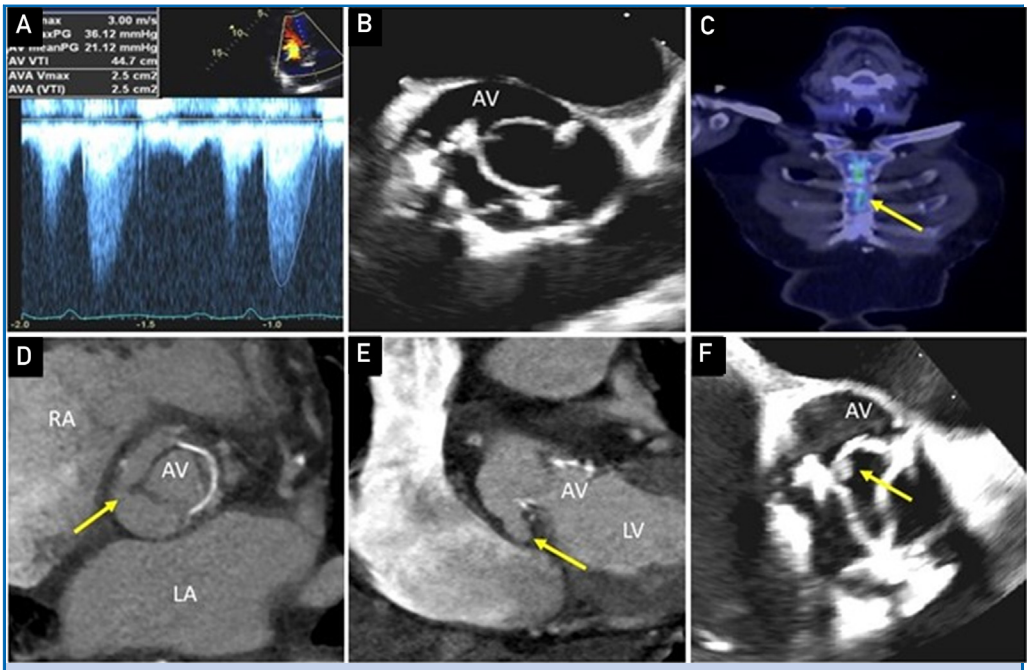

FIGURE 1. A 72-year-old man status post AV replacement with 23 mm Perigon Tissue Valve presented 4 years later with hemophagocytic lymphohistiocytosis. (A) Elevated prosthetic valve gradient on TTE. (B) Transesophageal echocardiography reports normal appearance of prosthetic valve. (C) Positron emission tomography-computed tomography moderate persistent FDG uptake along the sternotomy (arrow) with no uptake around the prosthetic valve. (D) Cardiac computed tomography reports partial dehiscence of the prosthetic ring (arrow), and (E) a pseudoaneurysm along the inferior noncoronary cusp (arrow). (F) Repeat TEE 2 months later reports a new 3 mm immobile mass (arrow) on the right coronary cusp of aortic prosthesis. AV, aortic valve; AVA, aortic valve area; FDG, fluorodeoxyglucose; LA, left atrium; LV, left ventricle; PG, peak gradient; RA, right atrium; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography; Vmax, Maximum velocity; VTI, velocity time integral.

treated with medical therapy alone, 3 because of prohibitively high surgical risk and 1 because of clinical stability. Toward the end of the follow-up period, 6 of the 12 patients were deceased or had transitioned to hospice, 2 of whom had progressed despite redo cardiovascular surgery.

DISCUSSION

We report the results of multimodality cardiovascular imaging in 12 patients with disseminated MC infections occurring after exposure to cardiopulmonary bypass machines, followed at a single tertiary referral center over a 10-year period. This is the first descriptive review focused on the salient cardiovascular imaging features of MC infections. Multimodality cardiac imaging is essential to the management of disseminated MC infections and can help establish a presumptive diagnosis in the setting of known exposure and typical symptoms. Serial imaging can identify patients with worsening infectious processes who would benefit from early surgical intervention. Supplemental Figure (available online at http://www.mcpiqojournal.org) highlights the challenges associated with the diagnosis and management of MC infections and proposes interventions to help improve outcomes.

In our series of 12 patients, 6 had confirmatory findings of MC infective endocarditis by imaging before the establishment of a microbiological diagnosis. Notably, 3 of these 6 patients had initial imaging classified as nonspecific for endocarditis, with identification of confirmatory findings on serial repeat imaging because of high clinical suspicion. Nonspecific findings included an unexplained increase in the gradient across the prosthetic valve, thickening of prosthetic valve leaflets

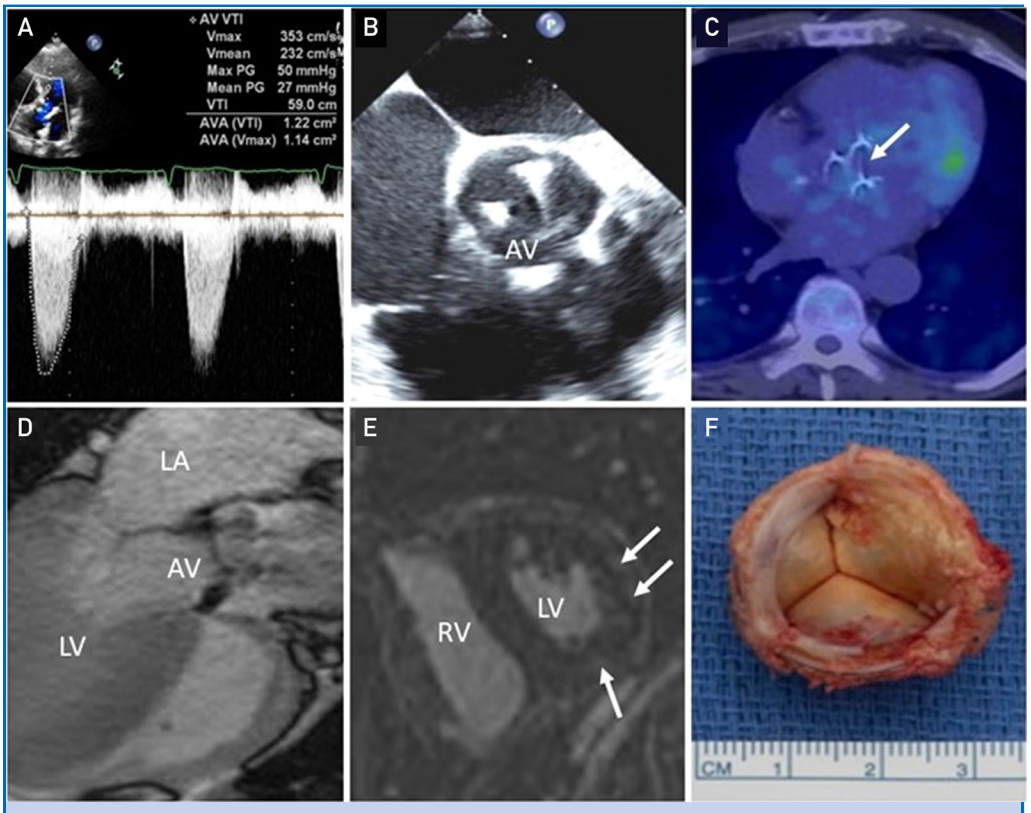

FIGURE 2. A 60-year-old man status post AV replacement with 25 mm Hancock II presented 3 years later with fatigue and weight loss. (A) Elevated prosthetic valve gradient on TTE. (B) Transesophageal echocardiography reports normal appearance of prosthetic valve. (C) Positron emission tomography-computed tomography negative for FDG uptake around AV prosthesis (arrow). (D) Cardiac magnetic resonance confirms prosthetic valve leaflet thickening, and (E) patchy midmyocardial delayed enhancement suggestive of myocarditis (arrows). (F) Surgically explanted valve reveals pannus ingrowth in the left cusp. AV, aortic valve; FDG, fluorodeoxyglucose; LA, left atrium; LV, Left ventricle; RV, right ventricle; TTE, transthoracic echocardiography.

without obvious vegetations, thickening of intervalvular fibrosa, and mild FDG uptake around the prosthetic material. Four of the 12 patients reported nonspecific findings that did not progress to confirmatory evidence of endocarditis despite serial imaging, with a subsequent confirmatory diagnosis established by microbiological testing. Two of the 12 patients had no evidence of infective endocarditis on imaging; however, they developed typical findings on serial imaging after the establishment of a microbiological diagnosis. Figures 1 and 2 highlight 2 representative cases with salient findings on multimodality imaging. These findings re-emphasize that classic findings of infective endocarditis are often absent in patients with MC, particularly early in the disease course.

Sommerstein et al[3] estimated a global burden of 156-282 cases of invasive MC infections per year. The association between disseminated MC infections in immunocompetent hosts with previous cardiovascular surgical exposure was first described in 2014,[2] with an outbreak of several cases identified subsequently in Europe and the United States. Through whole genome sequencing, the outbreak was traced to heater-cooler units used during cardiopulmonary bypass (LivaNova/Sorin 3T), likely contaminated during production in Germany.[1,8-10] Formal safety communications were issued by the European

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Center for Disease Prevention and Control and the US Food and Drug Administration in April and October 2015, respectively, with subsequent updates.[11,12] Despite this, new cases of MC infection continue to be identified in patients who have undergone surgery after 2015.[13]

The disease starts with aerosol contamination of a fresh surgical surface, rather than typical bacteremia, with a resulting endothelial injury cascade. The intracellular nature of the pathogen, unique biofilm properties, and the immunotolerance and lymphopenia associated with disseminated mycobacterial infections all contribute to the unusual and striking features of this disease—a prolonged latency period, widespread dissemination, difficult eradication despite appropriate medical or surgical therapy, and an alarmingly high mortality rate.[14] Prolonged antimicrobial therapy and definitive surgical interventions are the mainstays of treatment.[4,14] Microbiological diagnosis is challenging because of the slow growth and inability of commercial probes to isolate the MC from Microbacterium avium complex, requiring send-outs to a reference laboratory. Microbial cell-free deoxyribonucleic acid quantitative sequencing can provide more rapid results; however, its availability remains limited.[15,16]

The TTE and TEE are the initial modalities of imaging for suspected infective endocarditis. The challenges associated with echocardiography of prosthetic materials, such as reverberation artifacts and acoustic shadowing,[17] are particularly relevant in this population with previous cardiac surgery. Three-dimensional TEE provides better anatomical delineation, particularly the spatial relationship of coronary vessel origins to perianular pathology.[18] Although clinicians are attuned to relying on the modified Duke's criteria for diagnosing endocarditis, the diagnostic sensitivity is low in the setting of MC infection, similar to what was observed in patients after transcatheter aortic valve replacement.[7] There is a notable absence of bulky vegetations or regurgitant lesions, which are commonly associated with prosthetic valve endocarditis.[19] The TEE lends a higher spatial resolution and helps identify a larger proportion of patients with vegetations, periaortic abscesses, and aortic pseudoaneurysms.[20,21] More subtle findings included nonspecific thickening of the aortic root, thickening of the prosthetic valve leaflets, and characteristic absence of regurgitant lesions, often evolving into overt lesions of endocarditis on repeat imaging. Notably, surgical or prosthetic material specimens obtained from patients who underwent redo cardiovascular surgery were invariably positive for MC on microbial culture, even in those with nonspecific echocardiographic findings. Thus, it is essential that echocardiographic findings are interpreted in a critical manner by experienced readers. When initial findings are nonspecific, a strategy of short term follow-up imaging is suggested.

Electrocardiogram-gated cardiac CT provides multiplanar cine reconstructions, which are incremental and complementary to the data gathered by the echocardiography. Although TEE is more sensitive for small vegetations (<4 mm),[22] CT is superior for evaluation of anatomical extension of pathology.[19] Scriven et al[21] reported findings from one of the largest reviews on patients with MC and noted CT findings of mediastinal or aortic graft infections and fluid collections. In our cohort, CT played a important role in the management of 6 patients, with detection of pseudoaneurysms, periaortic abscess, dehiscence of prosthetic valve ring, and prosthetic valve thrombosis. Cardiac CT can also provide preoperative surgical risk assessment for sternal re-entry. Evaluation of coronary anatomy with CT may be preferred over invasive angiography to mitigate the risk of infectious embolization into the coronaries.

The role of cardiac MRI in the evaluation of suspected infective endocarditis is less established. Artifacts made from prosthetic material limit image quality. Three of our patients underwent cardiac MRI, with the most significant finding being identification of abnormally delayed enhancement of prosthetic valve leaflets and patchy, delayed midmyocardial enhancement in a noncoronary distribution, suggestive of myocarditis in the setting of disseminated MC infection. Cardiac MRI provides tissue characterization, particularly for assessment of myocardium for inflammatory or fibrotic changes with T2-weighted sequences and postgadolinium delayed enhancement sequences respectively. Images

obtained with a long inversion time (~600 ms) can help differentiate vegetations from other intracardiac masses such as thrombi. Although renal dysfunction may limit iodine-based contrast for CT imaging, MRI with gadolinium-based contrast has been deemed safer.[23]

The PET-CT with ^{18}F-FDG has a well-established role in the evaluation of prosthetic valve endocarditis[19] and vascular graft infections.[24] Studies have reported improved sensitivity for detection of endocarditis, although sometimes at the cost of reduced specificity.[25] However, it is notable that in our cohort, only 4 of ten patients had pathological FDG uptake associated with cardiovascular prosthetic material on PET-CT. It also helped identify the extent of dissemination, with 7 patients reporting uptake in noncardiac regions, such as bone marrow, spleen, and lungs, thus playing a key role in source control. Similar to our findings, previous reports have reported increased ^{18}F-FDG uptake around prosthetic material that appeared relatively unremarkable on other imaging modalities.[26] The major limitation here is the inability to differentiate endocarditis from other causes of inflammation, most relevant being ongoing tissue healing in this population with recent cardiac surgery.

LIMITATIONS

Because of the nature of this disease process, this is a limited retrospective analysis with a small sample size. The variation in choice and order of imaging modalities reflects the lack of established guidelines. These findings must be corroborated with larger studies as more cases are identified.

CONCLUSION

Disseminated MC infections continue to occur despite almost a decade of recognizing the root cause of the disease. The morbidity and mortality associated with this disease remain unacceptably high. Multimodality cardiovascular imaging plays an important role in the management of patients with MC infections and may help reduce the time to diagnosis, while awaiting confirmatory microbiological data. The intracellular nature of this pathogen, the unique biofilm component, and the degree of lymphopenia associated with disseminated mycobacteremia all contribute to a unique presentation with subtle and atypical findings on imaging. We propose that the current guidelines for the identification of typical infective endocarditis are not applicable to this patient population. The graphical abstract provides a suggested imaging approach on the basis of clinical suspicion and initial imaging findings. There is an urgent need to increase awareness among clinicians and cardiac imagers about this disease process, necessitating a high index of suspicion for the disease and a low threshold for repeat or alternative imaging when initial testing is equivocal.

POTENTIAL COMPETING INTERESTS

Dr Bennett reports payment or honoraria for lectures, presentations, speaker's bureaus, manuscript writing or educational events as a Course Director from Society of Critical Care Medicine, Critical Care Echo Board Review, and Mayo Clinic Foundation, Heart to Heart: Advances in Cardiac Critical Care and Resuscitation. The other authors report no competing interests.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **CT,** computed tomography; **FDG,** fluorodeoxyglucose; **MC,** *Mycobacterium Chimaera*; **MRI,** magnetic resonance imaging; **PET-CT,** positron emission tomography-computed tomography; **TEE,** transesophageal echocardiogram; **TTE,** transthoracic echocardiogram

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