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ORIGINAL RESEARCH

Global Practices in Cardiac Imaging for Cardiac Sarcoidosis

A Survey Study of International Experts With Delphi Consensus

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ABSTRACT

BACKGROUND Cardiac imaging is a cornerstone in the initial diagnosis, management, and follow-up of cardiac sarcoidosis. However, ordering thresholds, access, and follow-up imaging vary across the globe.

OBJECTIVES A Delphi study was conducted to define areas of consensus and areas requiring further study in the use of cardiac imaging in suspected or established cardiac sarcoidosis.

METHODS An international, multidisciplinary panel of experts in cardiac sarcoidosis completed a modified 2-round Delphi study. The study evaluated clinical decision making regarding the use of cardiac imaging, including indication thresholds, interpretation, and interval follow-up imaging. Consensus was defined a priori as ≥70% agreement or disagreement.

RESULTS A total of 89 experts in cardiac sarcoidosis (89 in round 1 and 75 in round 2) participated, representing 61 centers in 13 countries. Consensus was reached on 22 of 46 items (48%) in round 1 and 21 of 29 items (72%) in round 2. There was a low threshold to order advanced cardiac imaging for new rhythm abnormalities or ventricular dysfunction detected on echocardiography in patients with established extracardiac sarcoidosis. ^{18}F-fluorodeoxyglucose (FDG) positron emission tomography was an important co-primary modality with cardiac magnetic resonance (CMR) for initial diagnosis. If CMR was the first test, there was consensus to proceed to FDG-positron emission tomography after any abnormal CMR result or even after normal CMR result in the setting of moderate or high pretest probability for cardiac sarcoidosis. There was consensus that late gadolinium enhancement quantification was important, but there was no consensus on the threshold of risk or on how best to quantify late gadolinium enhancement. Similarly, reduction in FDG uptake was an important factor in guiding treatment response, but there was no consensus on how to best quantify FDG uptake or what constituted an adequate radiographic response.

CONCLUSIONS Several consensus areas for cardiac imaging in suspected and established cardiac sarcoidosis were identified. This consensus study identified areas of priority for future prospective, controlled, multicenter research studies. (JACC Cardiovasc Imaging. 2025;18:679-692) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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ABBREVIATIONS AND ACRONYMS

CMR = cardiac magnetic resonance

CS = cardiac sarcoidosis

CT = computed tomography

FDG = ^{18}F-fluorodeoxyglucose

Ga-67 SPECT = gallium-67 single-photon emission computed tomography

LGE = late gadolinium enhancement

PET = positron emission tomography

Cardiac sarcoidosis (CS) is characterized by granulomatous infiltration of the myocardium, which may cause life-threatening ventricular arrhythmias, heart block, and cardiomyopathy.[1] The condition is generally bifurcated into 2 groups of patients: those with pre-established extracardiac sarcoidosis such as pulmonary disease and those with de novo presentations of cardiac manifestations without a history of sarcoidosis. In addition, CS can exhibit clinically manifest or clinically silent presentations (ie, no cardiac manifestations, but with radiographic disease). Common clinical cardiac manifestations may include atrioventricular block, ventricular arrhythmias, or cardiomyopathy. Although the diagnosis and clinical phenotype require an integrated approach to clinical characteristics, cardiac investigations, histology, and exclusion of other conditions, advanced cardiac imaging with cardiac magnetic resonance (CMR), ^{18}F-fluorodeoxyglucose-positron emission tomography (FDG-PET), or gallium-67 single-photon emission computed tomography (Ga-67 SPECT) is ultimately an essential cornerstone for both diagnosis and management.

Despite the importance of advanced cardiac imaging in CS, there is significant heterogeneity between expert centers in the indications for ordering these tests, interpretation of imaging parameters, and the best approach to follow-up imaging. Imaging practices vary between geographic regions, between institutions within the same country, and even between providers at the same institution. This is due to the lack of controlled trials and prospective studies for this condition, as well as differences in access to more costly advanced cardiac imaging modalities between centers and geographic regions.[1] Medical societies have developed recommendation statements including the 2017 SNMMI-ASNC (Society of Nuclear Medicine and Molecular Imaging-American Society of Nuclear Cardiology) expert consensus document, 2017 European Association of Nuclear Medicine/European Association of Cardiovascular Imaging/ASNC joint procedural statement, 2018 Japanese Circulation Society recommendations, 2020 American Thoracic Society recommendations, and 2021 European Respiratory Society recommendations.[2-6] These have primarily focused on the rationale, indications, interpretation, optimal reporting, and diagnostic accuracy of multimodality cardiac imaging in CS. Recently, the American Heart Association formulated an expert statement that provided suggestions about some aspects of how to use advanced imaging for the diagnosis and management of sarcoidosis.[7] However, a common deficiency of these documents is the absence of guidance on optimal imaging thresholds and follow-up intervals, given the lack of prospective randomized trials and paucity of data in this area. We previously conducted a systematic review on PET imaging in CS, and this also demonstrated significant heterogeneity in center practices.[8]

The heterogeneity of practice and lack of clinical data in CS create an optimal environment for a Delphi consensus technique, which promotes independent thought, avoids direct confrontation between experts, and allows for the gradual development of a nuanced consensus approach.[9] The Delphi technique builds consensus through systematic, iterative rounds of questions, with refinement of the questions based on responses and consensus reached in the previous round.[10,11] In this Delphi study, we assembled a diverse panel of international experts in CS to identify areas of consensus on the clinical use of cardiac imaging for suspected and established CS.

METHODS

PARTICIPANT SELECTION. We established a steering committee of 13 experts in CS to develop the Delphi questionnaire and oversee the study process. The steering committee then helped recruit the expert panel with a goal of a balanced global representation of multidisciplinary experts in CS. A snowball recruitment process was used where each steering committee member provided the recommendations for expert panelists. An effort was made for diversity in participant sex, geographic location, and specialty. The expert panelist inclusion criteria were a physician whose practice directly involves the management or imaging of patients with CS, an expert in CS (as identified by the study team members) on the basis of academic or clinical contributions to the field, and an individual fluent in English for purposes of study communication.

DELPHI PROCESS. The expert panel included specialists from cardiology (advanced cardiac imaging,

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electrophysiology, advanced heart failure, and general cardiology), radiology, pulmonology, and rheumatology. A modified 2-round Delphi study was performed using an electronic, Research Electronic Data Capture (REDCap)-based questionnaire (REDCap 13.7.28, 2024 Vanderbilt University).[12,13] The first round was conducted between May 15, 2023, and June 15, 2023. Based on the results and feedback comments of the first round, a second questionnaire was developed. Because of the length of the survey, a more focused second round was derived from either: 1) the first-round questions that almost reached consensus; or 2) follow-up details of the first-round questions that had reached consensus. The prompts that almost reached consensus in the first round were revised to attempt to reach consensus in the second round. Using the same expert panelist list, a second round was conducted between August 29, 2023, and September 18, 2023. Consensus was defined a priori as ≥70% agreement or disagreement.[14,15] For questions with ordinal scales, we summed the total number agreeing for each threshold until 70% of the participants agreed or disagreed (lowest common denominator approach). Approval for this study was granted by the Cleveland Clinic Institutional Review Board.

GROUP DEFINITIONS FOR CS ACTIVITY. To better characterize CS activity, 4 phenotypes were identified on the basis of clinical presentation (clinically manifest vs clinically silent) and imaging findings:

- Group 1: *Clinically manifest, metabolically active CS:* Positive cardiac PET-CT (abnormal FDG uptake in a pattern consistent with CS) with or without abnormal CMR result (eg, nonischemic late gadolinium enhancement [LGE] and/or other findings of CS) and presence of clinical cardiac manifestations
- Group 2: *Clinically manifest, metabolically inactive CS:* Negative cardiac PET-CT (no FDG uptake) with abnormal CMR result (eg, nonischemic LGE and/or other findings of CS) and presence of clinical cardiac manifestations
- Group 3: *Clinically silent, metabolically active CS:* Positive cardiac PET-CT (abnormal FDG uptake in a pattern consistent with CS) with or without abnormal CMR result (eg, nonischemic LGE and/or other findings of CS) and no clinical cardiac manifestations
- Group 4: *Clinically silent, metabolically inactive CS:* Abnormal CMR result (eg, nonischemic LGE and/or other findings of CS) but negative current cardiac PET-CT and no current clinical cardiac manifestations

CRITERIA FOR PRETEST PROBABILITY. To better characterize the clinical suspicion for a new diagnosis of CS, 3 pretest probability scenarios were identified on the basis of symptoms and objective testing abnormalities. Objective testing abnormalities included abnormal cardiac enzymes with troponin, echocardiography, or rhythm abnormalities. The 3 pretest probabilities were as follows:

1. Low pretest probability: Symptoms in the absence of a convincing objective testing abnormality
2. Moderate pretest probability: Symptoms and 1 objective testing abnormality
3. High pretest probability: Symptoms and >1 objective testing abnormality

STATISTICAL ANALYSIS. Descriptive statistics were computed for all survey questions. Mean, frequency, and counts are reported.

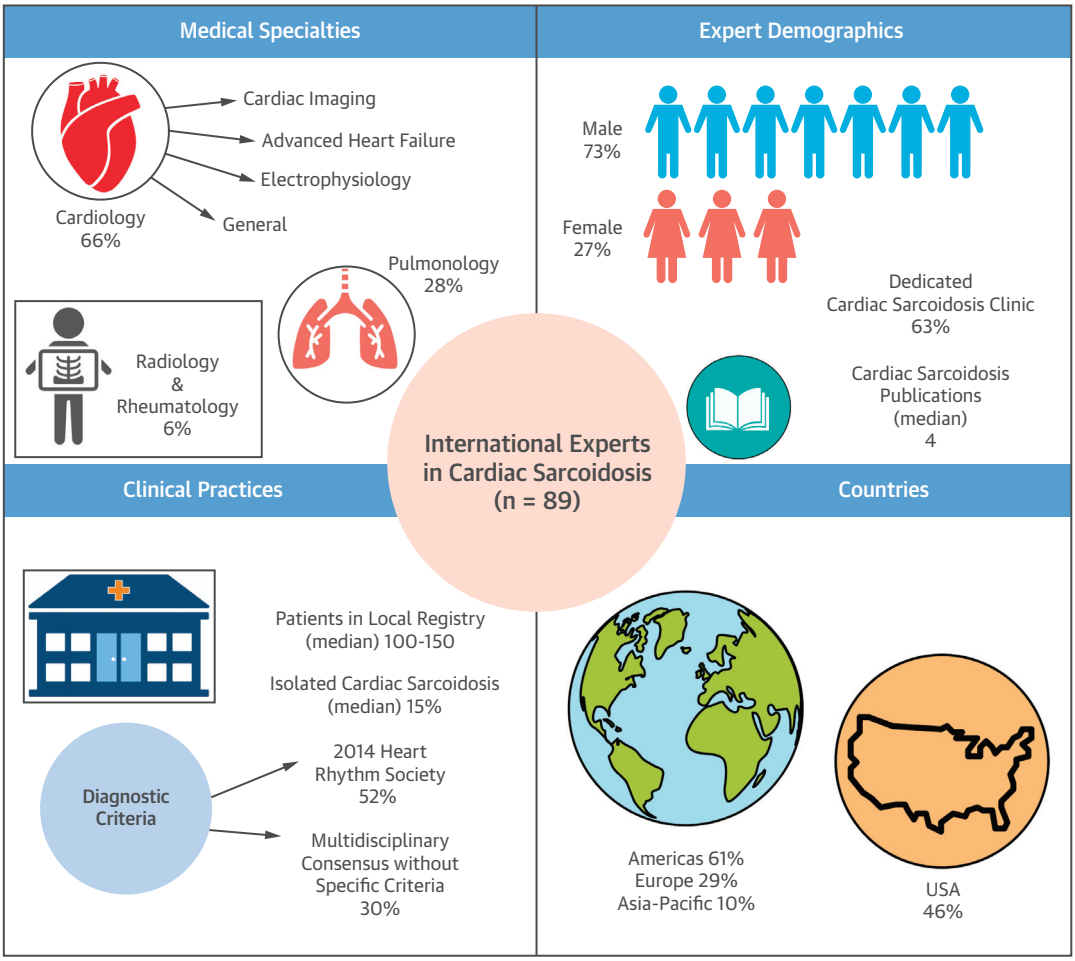
RESULTS

EXPERT PANELIST AND CENTER CHARACTERISTICS. A total of 89 CS experts (89 in round 1 and 75 in round 2) participated, representing 61 centers in 13 countries (**Figure 1**). Overall, consensus was reached on 22 of 46 items (48%) in round 1 and 21 of 29 items (72%) in round 2. The characteristics of the expert panel and practice patterns are listed in **Table 1** and Supplemental Table 1.

Dedicated CS clinics were common in the United States (28 of 41), as well as combined clinics (10 of 41). The United Kingdom (5 of 9) and the Netherlands (5 of 8) were also noted to have dedicated CS clinics. The characteristics of dedicated CS clinics included a multidisciplinary team, treatment and diagnosis group discussions, and regular team meetings. There is consensus agreement that multidisciplinary team discussion positively influenced management decisions for patients with CS (72% strongly agree).

ACCESS TO ADVANCED CARDIAC IMAGING. Access to advanced cardiac imaging varied across the globe (Supplemental Table 2). When assessing access to advanced cardiac imaging (CMR or PET) within 2 weeks on either an inpatient or an outpatient basis, the United States had better access (95%-98%) compared with outside the United States (67%-77%). This likely reflects the majority of expert panelists being from academic centers and is likely much lower in community/rural hospitals. Outside the United States, there was a higher level of access within 2 weeks on an inpatient basis, likely reflecting resource allocation and reimbursement practices globally. Acute inpatient settings appear to be

FIGURE 1 Characteristics of Experts in Cardiac Sarcoidosis



A total of 89 cardiac sarcoidosis experts (89 in round 1 and 75 in round 2) participated, representing 61 centers in 13 countries.

generally prioritized over outpatient settings for advanced cardiac imaging.

ROUND 1 AND 2 SURVEY RESULTS. **Rhythm.** Consensus was reached on 6 of 12 Likert scale questions (50%) (**Figure 2**, Supplemental Figure 1). Generally, there is a low threshold to order advanced cardiac imaging for new rhythm abnormalities in patients with established extracardiac sarcoidosis.

Of note, there is no consensus on the routine use of advanced imaging in those with first-degree atrioventricular block and atrial fibrillation. These are exceedingly common in elderly patients compared to the diagnosis of CS; hence, it is unclear that these common rhythm abnormalities would support routine use of advanced imaging modalities for screening in the absence of other symptoms or findings suggestive of CS.

Echocardiography. Consensus was reached on 5 of 10 Likert scale questions (50%) (**Figure 3**, Supplemental Figure 2). Generally, there is a low threshold to order advanced cardiac imaging for new left or right ventricular dysfunction detected on echocardiography in patients with established extracardiac sarcoidosis. Unexplained pericardial effusion and right ventricular dysfunction in patients with or without pulmonary sarcoidosis reached consensus on advanced imaging. However, neither abnormal left ventricular strain nor the use of right heart catheterization in cases of elevated right ventricular systolic pressure reached consensus to guide advanced cardiac imaging.

CMR. Consensus was reached on 5 of 11 (45%) Likert scale questions (45%) (**Figure 4**). LGE was overwhelmingly agreed upon as a risk factor for

adverse cardiac events, but consensus was not reached on how to quantify LGE, nor on the threshold above which LGE burden should be considered significant (Figure 5). When stratified by electrophysiology specialists only, consensus agreement was reached that "LGE burden should be used in procedural planning for EP VT ablation procedures."

There is consensus disagreement with the recommendation "Screening with CMR in asymptomatic extracardiac sarcoidosis is recommended once in a lifetime even in patients with normal ECG, echo and Holter." This is relevant because in the absence of cardiac symptoms or manifestations, it may not necessarily change management.

There is consensus disagreement with the recommendation "A normal CMR result (normal function and myocardial tissue characterization) definitively rules out cardiac sarcoidosis" (Figure 4). This recommendation is placed in the context of patients with moderate or high pretest probability, where an FDG-PET scan would play a complementary role. However, in patients with low-pretest probability, there was agreement that a negative first test with CMR is sufficient to conclude investigations for most patients.

FDG-PET imaging. Consensus was reached on 5 of 10 Likert scale questions (50%) (Figure 6). There is no consensus on how best to report or quantify FDG uptake on FDG-PET (Figure 5). Reduction in FDG uptake is agreed upon as an important factor in guiding treatment response, but complete resolution of FDG uptake as a treatment target did not reach consensus. Further, there is no consensus on how much FDG uptake reduction is acceptable and whether FDG uptake should be the dominant driver of decision making.

FDG-PET was an important co-primary modality with CMR for initial diagnosis. If CMR is the first test, there is consensus to proceed to FDG-PET imaging after any abnormal CMR result or even after normal CMR result in the setting of moderate or high pretest probability for CS. There is no consensus on how best to report or quantify FDG uptake on FDG-PET. A wide range of follow-up FDG-PET imaging intervals were reported but were generally guided by clinical response to immunosuppression. Of note, there is consensus agreement that perfusion imaging in addition to FDG uptake should be standard for imaging CS with FDG-PET.

Follow-up imaging. Consensus was reached on 5 of 10 Likert scale questions (50%) for surveillance imaging in clinically *manifest* CS (Figure 7). However, consensus was reached on only 2 of 9 Likert scale questions (29%) for surveillance imaging in clinically *silent* CS (Figure 8).

A wide range of practices were reported by experts concerning follow-up cardiac FDG-PET/computed tomography (CT) imaging intervals (Supplemental Figure 3). For example, 82% of the expert panel agreed to repeat FDG-PET/CT from >3 to 12 months after starting or increasing immunosuppression in patients who then have a *good* clinical response to treatment. Follow-up intervals were generally influenced by clinical response to immunosuppression, as 89% of the expert panel agreed to repeat FDG-PET/CT within 6 months of starting or increasing immunosuppression in patients who then have a *poor* clinical response to treatment. Follow-up intervals must consider the biologically reasonable time to expect a response to immunosuppression on FDG-PET, especially because

TABLE 1 Characteristics of Experts in CS (N = 89)

Male	65 (73)
CS publications, any	4 (1-9)
New CS patients per year, median	>25 (55)
Distribution	0-5 (3), 5-10 (12), 10-15 (10), 15-20 (7), 20-25 (12), >25 (55)
Total CS patients in center's clinical registry, median	100-150 (33)
Distribution	0-25 (3), 25-50 (9), 50-75 (15), 75-100 (12), 100-150 (33), other[a] (28)
Isolated CS (% of the total in a center's clinical registry)	15

	Results	
Specialty	**Round 1 (N = 89)**	**Round 2 (N = 75)**
Pulmonology, %	28	32
Cardiology, %	66	63
Subspecialty: cardiac imaging, %	25	21
Subspecialty: advanced heart failure, %	22	21
Subspecialty: electrophysiology, %	15	16
Subspecialty: general cardiology, %	6	4
Rheumatology, %	5	5
Radiology, %	1	0
Geography		
United States	41 (46)	
Outside of the United States	48 (54)	
Overall geographic distribution		
Americas (including the United States)	54 (61)	
Europe	26 (29)	
Asia-Pacific	9 (10)	
Clinical criteria used		
2014 Heart Rhythm Society criteria	46 (52)	
Multidisciplinary consensus without specific criteria	27 (30)	
2016 Japanese Circulation Society criteria	6 (7)	
WASOG Sarcoidosis Organ Assessment Tool	6 (7)	
Japanese Ministry of Health and Welfare criteria	4 (5)	

Values are n (%) or median (Q1-Q3), unless otherwise indicated. [a]Other: 300 (Q1-Q3: 250-400).
CS = cardiac sarcoidosis; WASOG = World Association for Sarcoidosis and Other Granulomatous Disorders.

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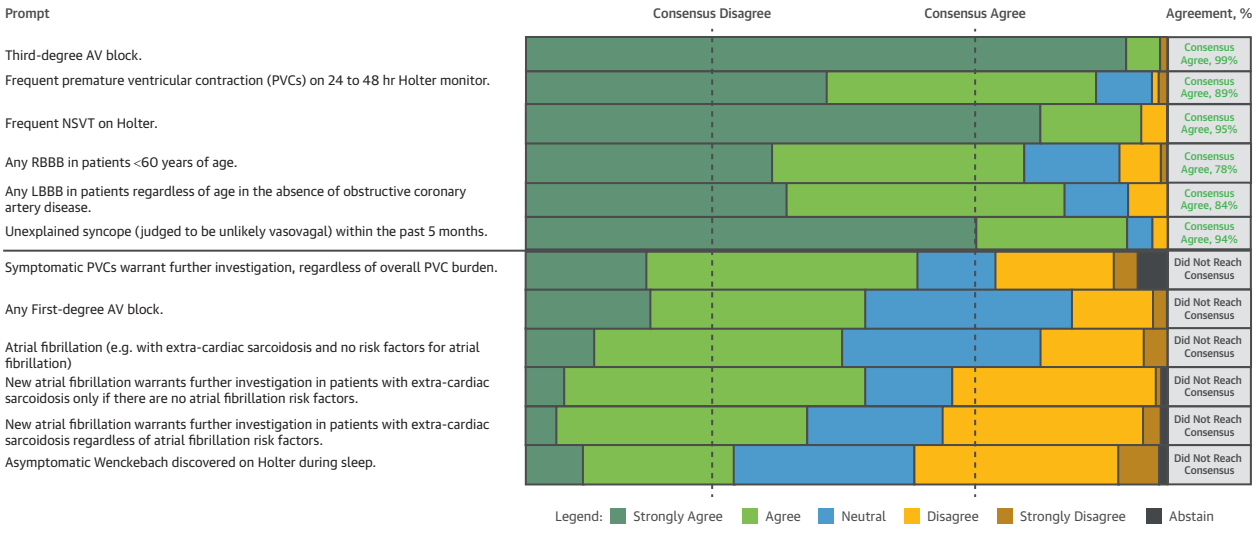
FIGURE 2 Expert Recommendations on Rhythm Abnormalities: Thresholds for Ordering Advanced Imaging

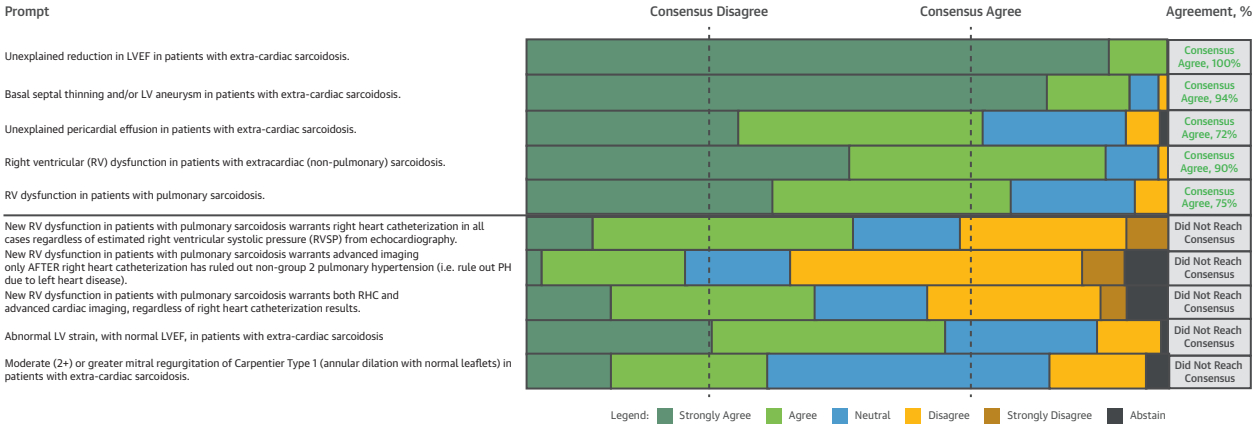


Abnormalities warranting advanced cardiac imaging in patients with extracardiac sarcoidosis but without established cardiac sarcoidosis. Generally, there is a low threshold to order advanced cardiac imaging for new rhythm abnormalities in patients with established extracardiac sarcoidosis. AV = atrioventricular; LBBB = left bundle branch block; NSVT = nonsustained ventricular tachycardia; RBBB = right bundle branch block.

certain disease-modifying antirheumatic drugs, such as methotrexate, may take up to 6 months to reach full effect.

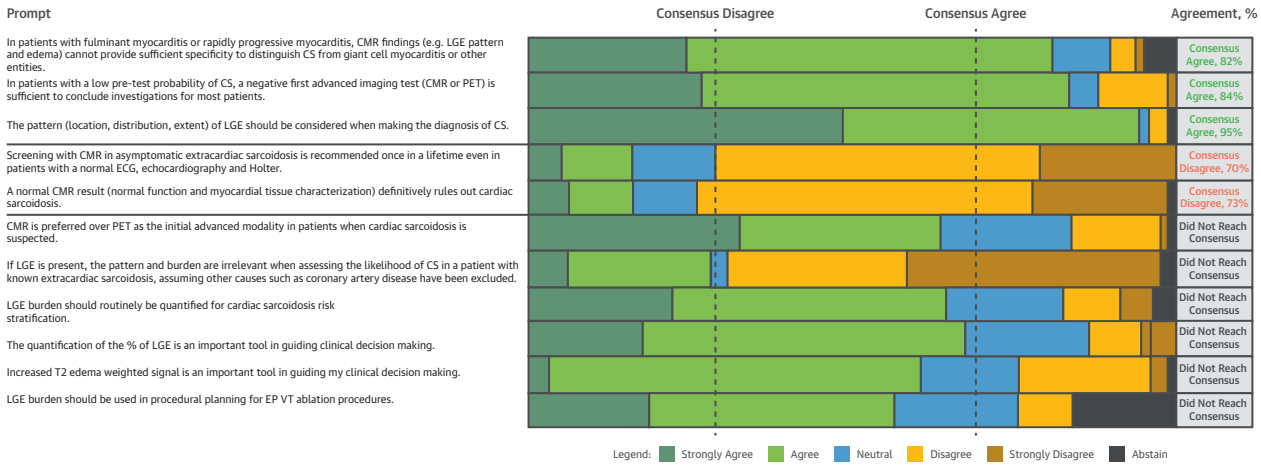
There is consensus disagreement with the recommendation that stable CS patients with immunosuppression should have yearly FDG-PET imaging indefinitely. In clinically stable patients, with or without immunosuppression, experts agree that repeating FDG-PET imaging indefinitely will not necessarily change management, accrues radiation risk, and is associated with high cost. A purposeful and time-limited follow-up approach was favored. A similar rationale drove the consensus disagreement with the following 2 recommendations: "All patients

FIGURE 3 Expert Recommendations on Echocardiographic Findings: Thresholds for Ordering Advanced Imaging



Abnormalities warranting advanced cardiac imaging. Generally, there is a low threshold to order advanced cardiac imaging for new left or right ventricular dysfunction detected on echocardiography in patients with established extracardiac sarcoidosis. Unexplained pericardial effusion and right ventricular dysfunction in patients with or without pulmonary sarcoidosis reached consensus on advanced imaging. LV = left ventricular; LVEF = left ventricular ejection fraction; PH = pulmonary hypertension; RHC = right heart catheterization.

FIGURE 4 Expert Recommendations and Interpretation of CMR



Late gadolinium enhancement (LGE) was overwhelmingly agreed upon as a risk factor for adverse cardiac events. Cardiac magnetic resonance (CMR) imaging findings must be interpreted in the correct context of pretest probability. Experts did not believe that a normal CMR result definitively ruled out cardiac sarcoidosis (CS) in patients with moderate or high pretest probability. CMR plays a complementary role to cardiac positron emission tomography (PET). ECG = electrocardiography; EP = electrophysiology; VT = ventricular tachycardia.

with CS should have yearly FDG-PET imaging for first 5 years postdiagnosis (regardless of clinical or immunosuppression status)" and "Stable CS patients not on immunosuppression should have yearly FDG-PET imaging indefinitely" (**Figure 7**).

CONSENSUS ON CUMULATIVE RESPONSE FOR FOLLOW-UP IMAGING. Because of the wide range of follow-up intervals reported by experts for repeat FDG-PET, no single response reached consensus agreement (Supplemental Figure 3). In this setting, we summed the cumulative ordinal responses to reach the 70% consensus threshold. For example, in the question "After starting or increasing immunosuppression in patients who then have a good clinical response to treatment, how soon should FDG PET/CT be repeated?" the 2 summing the votes in favor of 3 to 6 months (41%) and those in favor of 6 to 12 months (42%) allowed us to reach consensus that imaging should be obtained at least within 12 months, without consensus that it should be obtained sooner than 6 months. In the **Central Illustration**, this is reported as "Within 3-12 months" for simplicity and noted in the color legend as representing a "Consensus on cumulative response." Lastly, there is a lack of consensus on how to monitor clinically silent CS and whether this was even necessary in the absence of any cardiac manifestations.

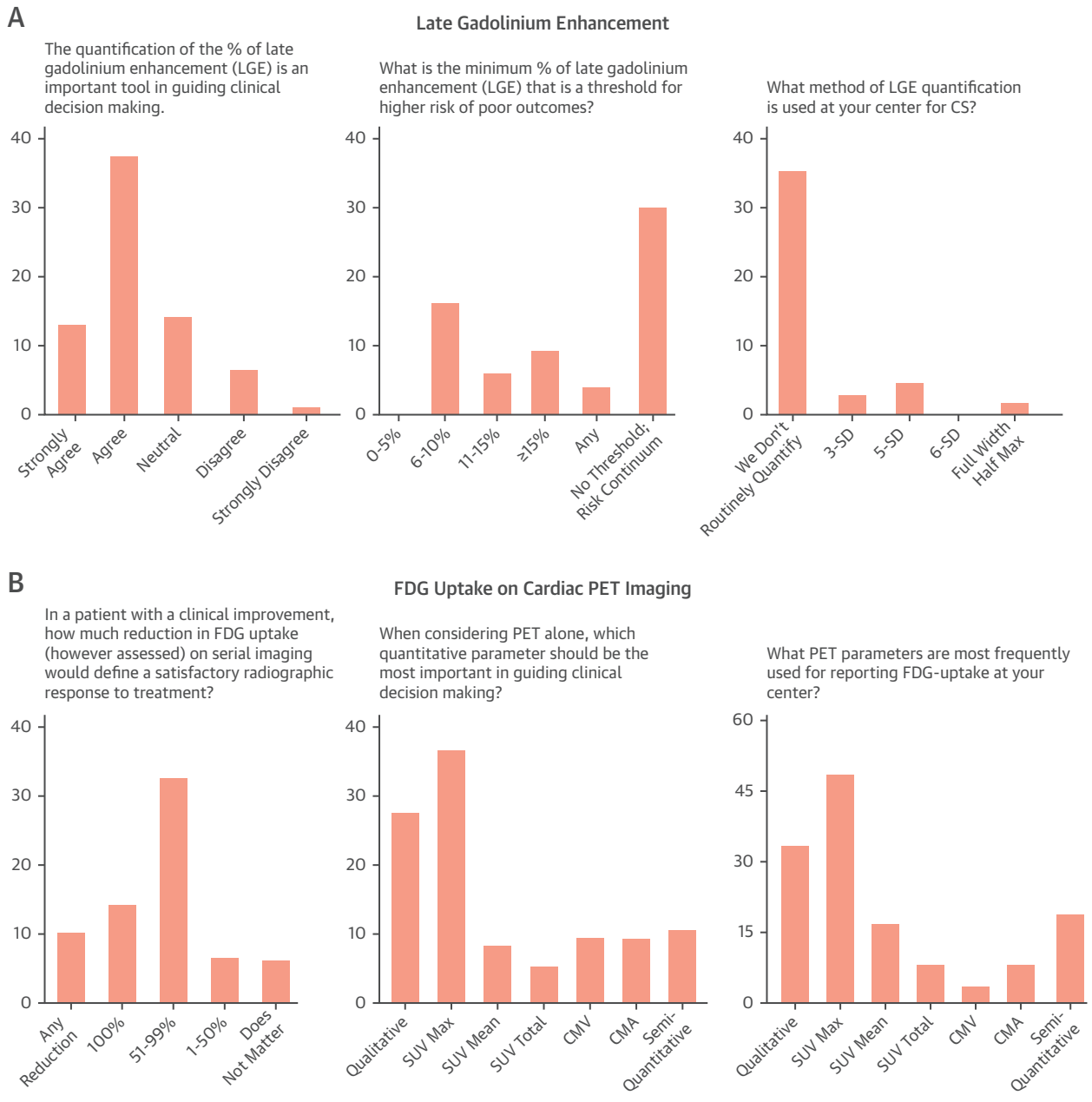
SENSITIVITY ANALYSIS BY SPECIALTY. To evaluate whether significant differences exist between experts by specialty, we performed 3 sensitivity analyses (Supplemental Tables 3 to 5). These included changes in recommendations when stratified by: 1) cardiac imagers (advanced cardiac imaging and radiology); 2) cardiologists alone (all subspecialities); and 3) cardiologists excluded. Of the 75 total prompts, between 8 and 12 (11%-16%) were reclassified in each analysis. This was a relatively low amount and reassures us that the overall results of the study are reflective of the current state of CS knowledge among varying specialty experts.

There were some noteworthy differences between specialties. For example, cardiac imagers reached consensus agreement on the prompts "Complete resolution of FDG uptake should be a treatment target of immunosuppression in CS," that *qualitative* FDG-PET is most frequently reported at their center, and that LGE was *not* routinely quantified at their center. Noncardiologists reached consensus on using left ventricular strain detected on echocardiography to guide advanced imaging, that yearly echocardiography should be used to monitor CS, and that any frequent nonsustained ventricular tachycardia warrants advanced cardiac imaging.

DISCUSSION

In this Delphi study of CS involving a large number of multidisciplinary, international experts, consensus was reached on many issues. This expert opinion

FIGURE 5 Trends in Quantification of LGE and FDG

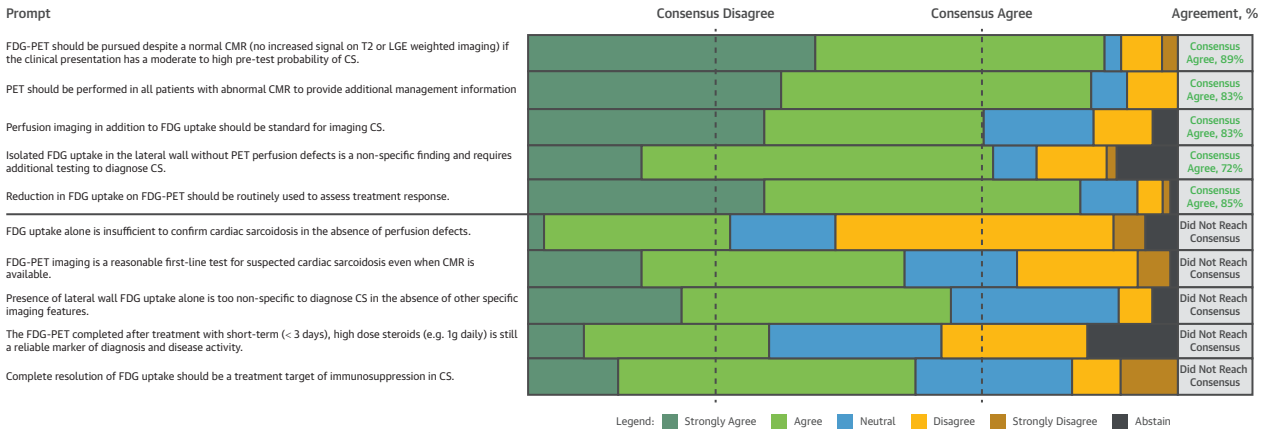


This figure shows trends in quantification of LGE on CMR (A) and ^{18}F-fluorodeoxyglucose (FDG) uptake on FDG-PET (B). Consensus was not reached on how to quantify LGE, nor on the threshold above which LGE burden should be considered significant. There is no consensus on how best to report or quantify FDG uptake on cardiac FDG-PET. CMA = cardiac metabolic activity; CMV = cardiac metabolic volume; SUV = standardized uptake value; other abbreviations as in Figure 4.

provides practical guidance to clinicians where rigorous clinical evidence is lacking. In addition, given that consensus was not reached on several issues concerning cardiac imaging in patients with suspected or established cardiac sarcoidosis, we identified issues that may be particularly relevant for future clinical investigations. A summary of the key findings from the study is presented in Table 2.

The complementary value of CMR and FDG-PET was reinforced in this Delphi study. The diagnostic work-up of CS with advanced cardiac imaging is generally dependent on the clinical pretest

FIGURE 6 Expert Recommendations and Interpretation of FDG-PET Imaging

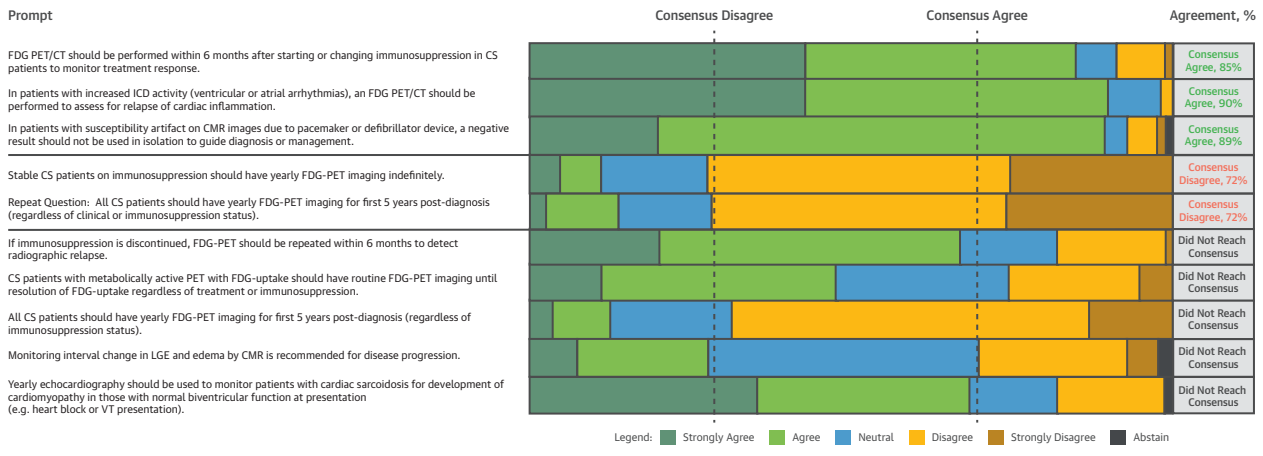


Reduction in FDG uptake is agreed upon as an important factor in guiding treatment response, but complete resolution of FDG uptake as a treatment target did not reach consensus. There is no consensus on how much FDG uptake reduction is acceptable and whether FDG uptake should be the dominant driver of clinical decision making. Abbreviations as in Figures 4 and 5.

probability. Negative CMR for the initial diagnosis of CS in the setting of low pretest probability is sufficient to conclude investigations. If CMR was the first test, there was consensus to proceed to FDG-PET after abnormal CMR result or even after normal CMR result in the setting of moderate or high pretest probability for CS (Central Illustration, A). A wide range of follow-up intervals for repeat FDG-PET imaging were reported, and these were generally influenced by clinical response to immunosuppression (Central Illustration, B).

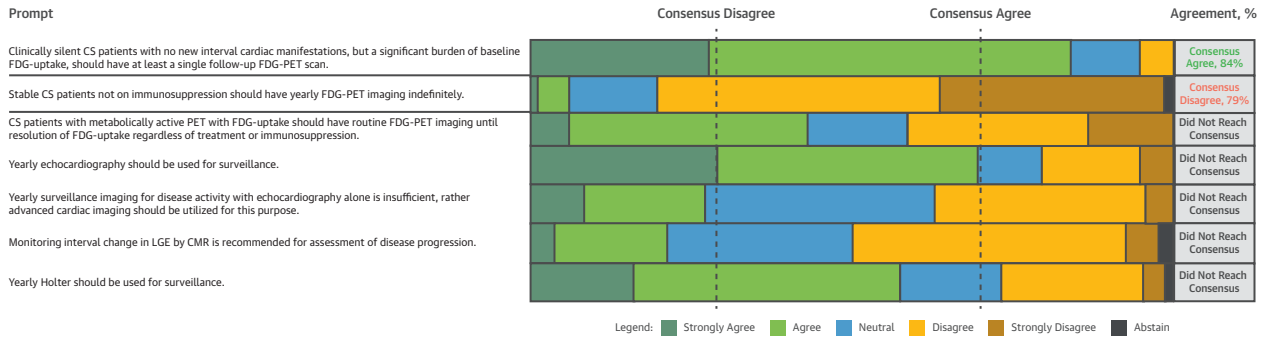
LGE has been identified as a risk factor for adverse cardiac events, and most experts agreed that LGE quantification was important.[1,16] However, there is a lack of consensus on the percentage risk threshold for LGE and most centers did *not* routinely quantify LGE (Figure 5). Notably, a study by Athwal et al[17] assessed LGE patterns visually, including pathology-frequent and pathology-rare LGE patterns that were correlated with histological findings. They found that visually identified, pathology-frequent LGE patterns

FIGURE 7 Expert Recommendations on Surveillance Imaging in Clinically Manifest CS



Clinically manifest = presence of cardiac symptoms such as ventricular arrhythmia, high-grade heart block, cardiomyopathy, or heart failure; CT = computed tomography; ICD = implantable cardioverter-defibrillator; other abbreviations as in Figures 4 and 5.

FIGURE 8 Expert Recommendations on Surveillance Imaging in Clinically Silent CS



Clinically silent = absence of cardiac symptoms; other abbreviations as in Figure 7.

were significantly associated with arrhythmia and heart failure. Thus, there may be value in both qualitative and quantitative reporting of LGE in CS.

FDG uptake was also identified as a risk factor for adverse cardiac events, and reduction in FDG uptake was an important factor for guiding treatment response. However, there is no consensus on how best to quantify FDG uptake (Figure 5). Many centers use >1 quantification technique. The most common methods to report FDG uptake are qualitative (46%) and maximum standardized uptake value (66%). Despite the lack of consensus on how best to report FDG uptake and which parameter is most important to guide clinical decision making, a satisfactory radiographic response was most commonly defined as FDG reduction between 51% and 99% (43%).

Several society statements on cardiac imaging discuss the diagnostic and prognostic value of advanced cardiac imaging in CS, including the Joint SNMMI-ASNC expert consensus document on the role of ^{18}F-FDG PET/CT in cardiac sarcoid detection and therapy monitoring, the HRS (Heart Rhythm Society) 2014 expert consensus statement on the diagnosis and management of arrhythmias associated with cardiac sarcoidosis,[1,2,5] and 2020 clinical practice guideline by the American Thoracic Society. Although these statements do discuss cardiac imaging, none provide operational guidance on imaging thresholds and timing of follow-up imaging. In contrast, the 2024 AHA (American Heart Association) statement provides suggestions about the timing of repeat imaging. However, our Delphi study used a rigorous methodology with a specific threshold for consensus, involved a much larger number of experts, and also provides insight into the extant degree of uncertainty around these issues.

The present study adds to the published data with clinically useful diagnostic algorithms based on data provided by our collective of international experts in this Delphi study (Central Illustration). Although several consensus areas for advanced cardiac imaging in CS were identified, there is also limited consensus on many important decision-making junctures. A wide range of practices exist in the context of limited objective data. This consensus study identified research priorities and opportunities for prospective, controlled, multicenter research studies. This also supports the role of multidisciplinary centers of excellence to promote expert-led discussion and guidance for diagnosis and management at a local level.

STUDY LIMITATIONS. A number of limitations of this Delphi study are worth discussing. First, although this was a large, multicenter Delphi consensus study, the response rate decreased slightly in the second round with attrition of 14 out of the 89. Second, the expert panelists in this study worked primarily in academic centers and had higher levels of access to advanced cardiac imaging than did those in regional or rural community hospitals. Third, our results may have been biased by differences in care throughout the world. Almost all responses of no easy access to cardiac studies or only inpatient access within 2 weeks were from investigators outside the United States. Specifically, outside the United States, there was relatively less timely outpatient access to advanced imaging, with easy access being typically limited to hospitalized patients. This may reduce generalizability of recommendations. Further, some parts of the world that lack PET equipment rely more on Ga-67 SPECT imaging for CS. This study did not focus on Ga-67 SPECT. Fourth, although an effort was

CENTRAL ILLUSTRATION **Proposed Algorithms for Cardiac Imaging in Suspected and Established Cardiac Sarcoidosis**

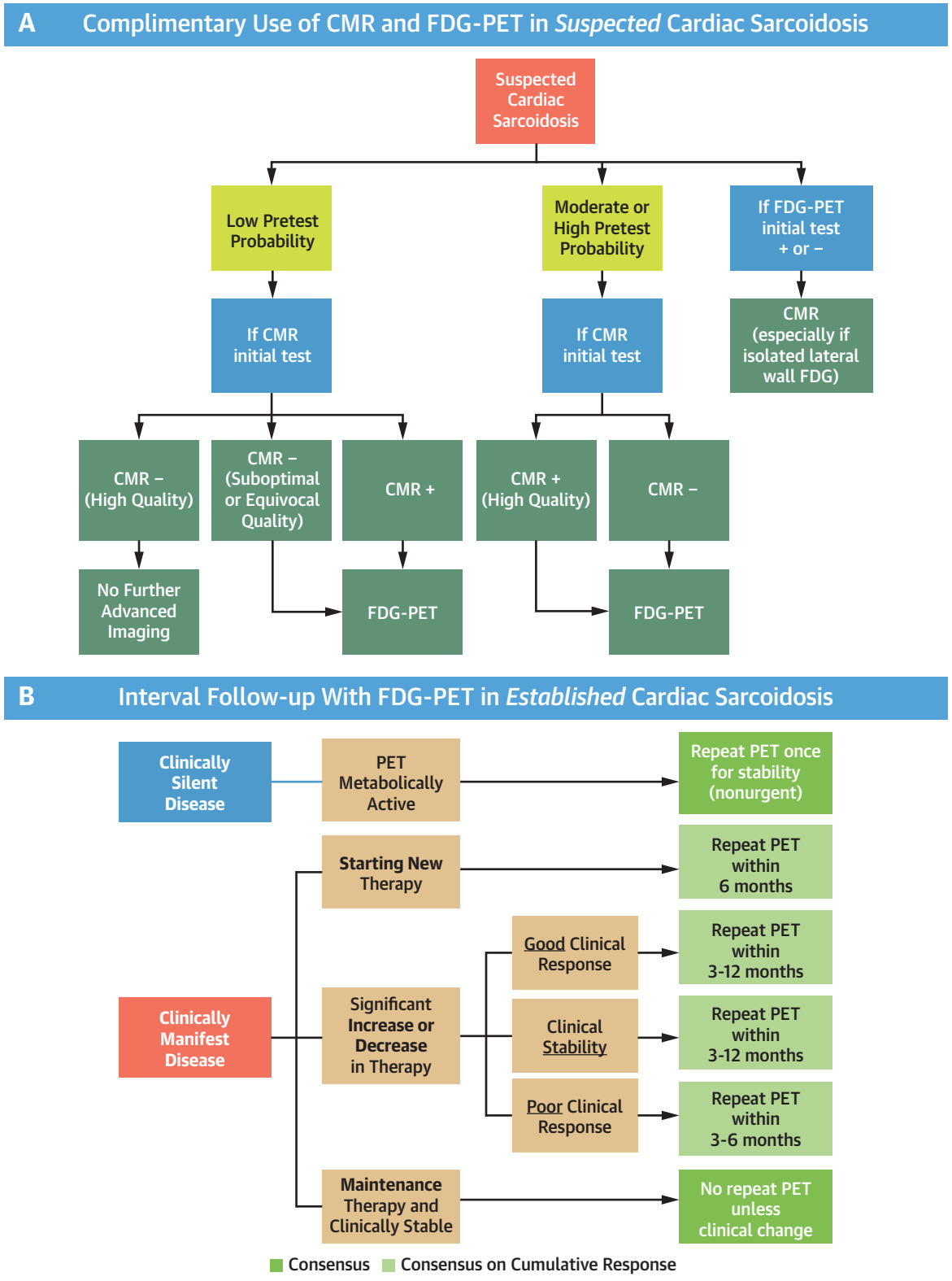


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TABLE 2 Summary of Key Messages From the Study

1. There is a low threshold to order advanced cardiac imaging for new rhythm abnormalities in patients with established extracardiac sarcoidosis. However, this must be balanced against the common prevalence of first-degree AV block, atrial fibrillation, and left or right bundle branch block in elderly patients and in those with other cardiac risk factors.
2. There is a low threshold to order advanced cardiac imaging for any new left or right ventricular dysfunction detected on echocardiography in patients with established extracardiac sarcoidosis. Neither abnormal left ventricular strain nor the use of right heart catheterization in cases of elevated RVSP reached consensus to guide advanced cardiac imaging.
3. LGE is overwhelmingly agreed upon as a risk factor for adverse cardiac events, but how to quantify LGE and how much LGE should be considered significant did not reach consensus.
4. Interpretation of CMR is generally done in conjunction with clinical pretest probability. Negative CMR in the setting of low pretest probability is sufficient to conclude investigations for most patients, but negative CMR in the setting of moderate or high pretest probability does not rule out cardiac sarcoidosis.
5. FDG-PET is an important co-primary modality with CMR for initial diagnosis. If CMR was the first test, there is consensus to proceed to FDG-PET after any abnormal CMR result or even after normal CMR result in the setting of moderate or high pretest probability for cardiac sarcoidosis.
6. There is no consensus on how best to report or quantify FDG uptake on FDG-PET. A wide range of follow-up FDG-PET imaging intervals were reported but were generally guided by clinical response to immunosuppression.
7. Reduction in FDG uptake is agreed upon as an important factor in guiding treatment response, but complete resolution of FDG uptake as a treatment target did not reach consensus. Further, there was no consensus on how much FDG uptake reduction was acceptable and whether FDG uptake should be the dominant driver of decision making.
8. There is a lack of consensus on how to monitor clinically silent cardiac sarcoidosis and whether this was even necessary in the absence of any cardiac manifestations.
9. There is limited consensus on many important decision-making junctures, suggesting the need for expert integration of both clinical and advanced cardiac imaging factors. The lack of consensus also underscores the role of multidisciplinary centers of excellence in guiding diagnosis and management.
10. A wide range of practices exist in the context of limited objective data. This consensus study identified research priorities and opportunities for prospective, controlled, multicenter research studies.

AV = atrioventricular; CMR = cardiac magnetic resonance; FDG = ^{18}F-fluorodeoxyglucose; LGE = late gadolinium enhancement; PET = positron emission tomography; RVSP = right ventricular systolic pressure.

made to include geographic diversity, certain regions such as Africa, Japan, and East Asia were underrepresented (Asia-Pacific: 10%). Fifth, although efforts were made to include more radiologists, nuclear medicine physicians, and pathologists, the majority of respondents were cardiologists. Sixth, the lack of consensus on the technical aspects of imaging, such as LGE quantification and FDG measurement, may have been related to inclusion of nonimagers. However, when we analyzed statements that failed to reach consensus in detail, such as restricting the imaging statements to cardiac imaging specialists only, we found that many statements that had failed to reach consensus among the entire expert panel remained without consensus in the cardiac imaging group (Supplemental Table 3). Lastly, the management of CS requires a multidisciplinary team of specialized perspectives. Although all the questions in this survey were administered to all our diverse group of experts, not all of them will have the same level of expertise across all areas. Although the option to abstain from a scenario was provided, it is conceivable that the respondents did not have adequate knowledge to offer expert opinion on some of the survey questions. Accordingly, areas that lack consensus should not be used to signify lack of benefit, and areas with consensus agreement do not necessarily imply that such practices are always beneficial. Ultimately, clinicians should continue to rely on multidisciplinary team approaches for optimizing patient care.

FUTURE DIRECTIONS AND RESEARCH PRIORITIES. This study identified several areas requiring further study. First, although there is consensus that multidisciplinary clinic and management are the preferred approach in CS, there is presently no evidence that

CENTRAL ILLUSTRATION Continued

(A) Complementary use of cardiac magnetic resonance (CMR) imaging and ^{18}F-fluorodeoxyglucose–positron emission tomography (FDG-PET) when cardiac sarcoidosis is suspected. Colors are for illustrative purposes only and not strength of recommendation. (B) Follow-up interval with FDG-PET in patients with established cardiac sarcoidosis. Color legend on the bottom left. The red and blue color boxes are for illustrative purposes only. Clinically manifest = presence of cardiac symptoms such as ventricular arrhythmia, high-grade heart block, cardiomyopathy, or heart failure; Clinically silent = absence of cardiac symptoms. Pretest probabilities: Low pretest probability = symptoms in the absence of a convincing objective testing abnormality such as abnormal cardiac enzymes with troponin, echocardiography, or rhythm abnormalities; Moderate pretest probability = symptoms and 1 objective testing abnormality; High pretest probability = symptoms and >1 objective testing abnormality.

this leads to better outcomes. Studies evaluating optimal CS management approaches may help in this regard. Second, reporting and interpretation of LGE on CMR varies. Further research is needed to standardize approaches and evaluation of whether there is a risk threshold for LGE burden, as has been established in other conditions such as hypertrophic cardiomyopathy (eg, 15% LGE).[18] Third, FDG uptake evaluation and quantification vary. Further research is needed on standardizing these approaches and whether the multitude of quantitative parameters has value in outcomes. Fourth, the definition of treatment response on FDG-PET varies. This is an important aspect of immunosuppression management, and we believe research determining the optimal response thresholds and quantification approaches would be clinically impactful. Lastly, a wide range of follow-up FDG-PET time intervals were identified. Further studies are needed on whether follow-up FDG-PET scanning has any role in improving outcomes and, if so, at what interval. Overall, there is a need for societal and international collaboration to address the identified research gaps as well as disparities across the regions.

CONCLUSIONS

Overall, this international, multidisciplinary Delphi consensus study identified several consensus recommendations for cardiac imaging in suspected and established CS. However, a wide range of clinical practices were also identified in the context of limited data to guide management. This study identified research priorities and opportunities for future prospective, controlled, multicenter research trials.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: In a large, international, multidisciplinary Delphi study of experts in cardiac sarcoidosis, several consensus recommendations were identified for cardiac imaging in suspected and established cardiac sarcoidosis.

TRANSLATIONAL OUTLOOK: A wide range of practices exist in the context of limited objective data. This consensus study identified areas of priority for future prospective, controlled, multicenter research studies.

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KEY WORDS cardiac imaging, cardiac magnetic resonance, cardiac sarcoidosis, Delphi technique, diagnosis, echocardiography, FDG-PET, follow-up, sarcoidosis

APPENDIX For a list of Cardiac Sarcoidosis Expert Panelists as well as supplemental figures and tables, please see the online version of this paper.

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