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Canadian Association of Radiologists Cardiovascular Imaging Referral Guideline

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Abstract

The Canadian Association of Radiologists (CAR) Cardiovascular Expert Panel is made up of physicians from the disciplines of radiology, cardiology, and emergency medicine, a patient advisor, and an epidemiologist/guideline methodologist. After developing a list of 30 clinical/diagnostic scenarios, a rapid scoping review was undertaken to identify systematically produced referral guidelines that provide recommendations for one or more of these clinical/diagnostic scenarios. Recommendations from 48 guidelines and contextualization criteria in the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) for guidelines framework were used to develop 125 recommendation statements across the 30 scenarios (27 unique scenarios as 2 scenarios point to the CAR Thoracic Diagnostic Imaging Referral Guideline and the acute pericarditis subscenario is included under 2 main scenarios). This guideline presents the methods of development and the referral recommendations for acute chest pain syndromes, chronic chest pain, cardiovascular screening and risk stratification, pericardial syndromes, intracardiac/pericardial mass, suspected valvular disease cardiomyopathy, aorta, venous thrombosis, and peripheral vascular disease.

Résumé

Le groupe d'experts en radiologie du système cardiovasculaire de l'Association canadienne des radiologistes (CAR) regroupe des radiologistes, des cardiologues, des urgentologues, une représentante des patients et une épidémiologiste spécialisée en méthodologie de l'élaboration de lignes directrices. Après avoir élaboré une liste de 30 scénarios cliniques/diagnostiques, le groupe d'experts a entrepris une revue rapide de délimitation du problème en vue de repérer les lignes directrices relatives aux demandes d'examen produites de façon systématique qui fournissent des recommandations pour un ou plusieurs de ces scénarios. Les recommandations de 48 lignes directrices et critères de contextualisation du cadre GRADE (notation des recommandations, analyses, développements et évaluations) concernant la structure des lignes directrices ont été utilisées pour rédiger 125 énoncés de recommandations couvrant les 30 scénarios (27 de ces scénarios sont uniques; deux se réfèrent aux lignes directrices de la CAR relatives aux demandes d'examen en imagerie diagnostique du thorax et la section concernant la péricardite aiguë est dupliquée pour se retrouver sous deux scénarios principaux). Ces lignes directrices présentent les étapes à suivre et les recommandations de demandes d'examen dans le cas de syndromes de douleur thoracique aiguë,

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de douleurs thoraciques chroniques, de dépistage cardiovasculaire et de stratification du risque, de troubles du péricarde, de masses du cœur ou du péricarde, de valvulopathies présumées, de cardiomyopathies, de problèmes liés à l'aorte, de thromboses veineuses et de maladies vasculaires périphériques.

Keywords
cardiovascular, heart, peripheral vascular disease, diagnostic imaging, referrals, guideline

Introduction

Beginning in February 2023, an Expert Panel (EP) made up of physicians from the disciplines of radiology, cardiology, and emergency medicine, a patient advisor, and an epidemiologist/guideline methodologist met to develop a new set of recommendations specific to referral pathways for cardiovascular conditions. Through discussion (via a virtual meeting) followed by offline communication, the EP developed a list of 30 clinical/diagnostic scenarios to be covered by this guideline. These recommendations are intended primarily for referring clinicians (eg, family physicians, specialty physicians, nurse practitioners); however, they may also be used by radiologists, individuals/patients, and patient representatives.

Our methods describing the guideline development process, including the rapid scoping review to identify the evidence base, has been published in *CMAJ Open*[1] and an editorial to this series of guideline publications is available in *CARJ*.[2] The application of well-established scoping review and rapid review guidance (JBI,[3] Cochrane Handbook,[4] Cochrane Rapid Review Methods Group[5]) and guideline methodology (ie, Grading of Recommendations Assessment, Development, and Evaluation or GRADE[6,7]) were used to identify the evidence-base and to guide the Expert Panel in determining the strength and direction of the recommendations for each clinical scenario (Table 1). The quality of conduct and reporting of the included guidelines identified in the scoping review were evaluated with the AGREE-II checklist,[8] using a modified scoring system. In instances where guidelines were lacking, expert consensus was used to develop the recommendation. Contextualization to the Canadian health care system was considered for each recommendation, with discussion around the factors found in the Evidence to Decision framework in GRADE for guidelines (eg, balance of desirable and undesirable outcomes, values and preferences, resources implications).[7]

A systematic search for guidelines (with an a priori defined inclusion criteria) was run in Medline and Embase on March 30, 2023. The search was limited to publications from 2018 onward (Supplemental Appendix 1). Supplemental searching included the following national radiology and/or guideline groups: the American College of Radiology, the National Institute for Health and Care Excellence, and the Royal College of Radiologists 8th Edition (2017). Recommendations for each clinical scenario were formulated over one virtual meeting in September 2023. External review and feedback were obtained from radiologists, a nuclear medicine radiologist, and an emergency physician. The full guideline can be found on the CAR website (www.car.ca).

Table 1. Recommendation Text, Symbol, and Interpretation.

Recommendation	AGAINST	FOR
STRONG	**Strong, against** "we recommend against" (↓↓) • All or almost all informed people would not recommend/choose the course of action and only a small proportion would.	**Strong, for** "we recommend" (↑↑) • All or almost all informed people would recommend/choose the course of action and only a small proportion would not. • Request discussion if the intervention is not offered.
CONDITIONAL	**Conditional, against** "we suggest against" (↓) • Most informed people would not recommend/choose the course of action, but a substantial number would. • This may be conditional upon patient values and preferences, the resources available or the setting in which the intervention will be implemented.	**Conditional, for** "we suggest" (↑) • Most informed people would recommend/choose the course of action, but a substantial number would not. • This may be conditional upon patient values and preferences, the resources available or the setting in which the intervention will be implemented.

Note. Down arrows are red and Up arrows are green when available in colour.
Created using the guidance provided in Andrews et al.[6]

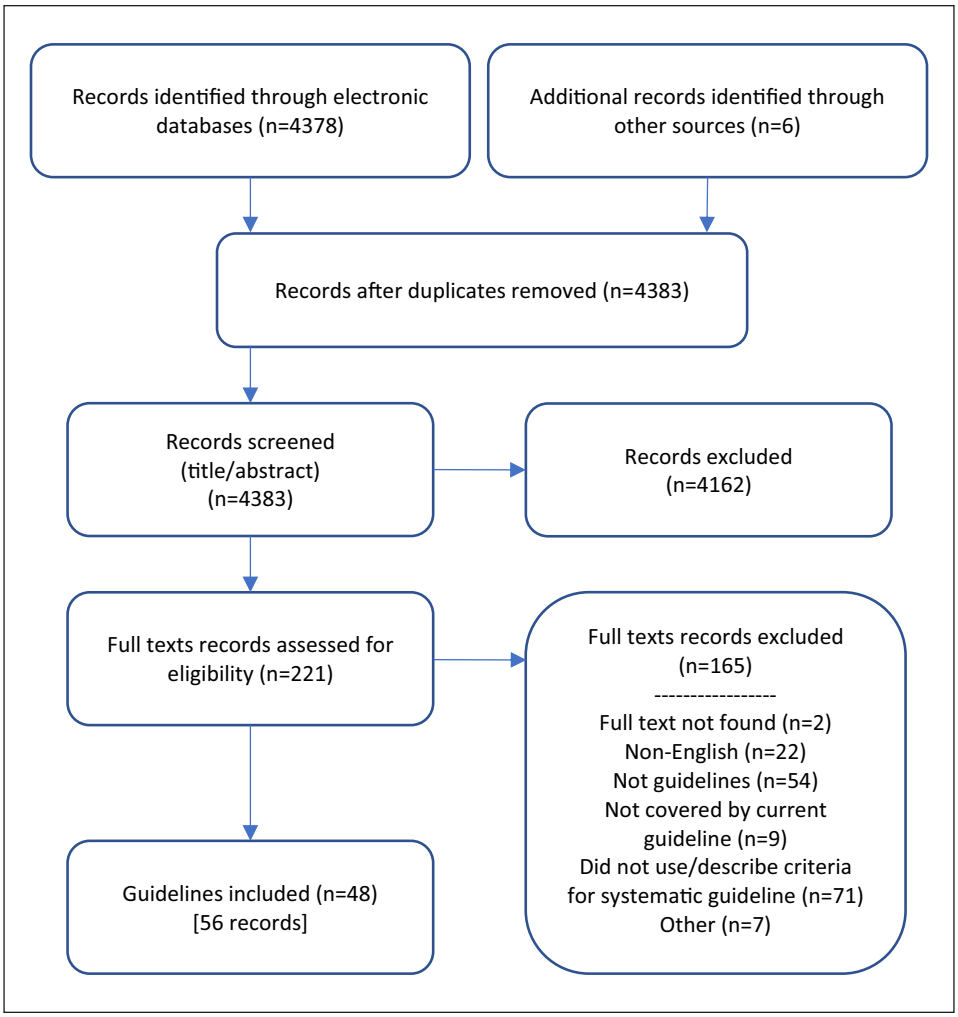

Figure 1. PRISMA flow diagram.

Results

Systematic Scoping Review

A total of 4379 records were identified through the electronic database and 6 additional records were added from the supplemental search. Forty-eight guidelines, plus 8 companion papers, were included (Figure 1). Potentially relevant guidelines published in languages other than English can be found in Supplemental Appendix 2. A list of excluded records with justifications for exclusion is available upon request. Most guidelines were rated as moderate or high quality, using the modified AGREE-II checklist[8] (Supplemental Appendix 3). The number of guidelines included per clinical/diagnostic scenario ranged from 1 to 10, with a median of 5 guidelines per clinical scenario.

Recommendations

Additional details of the included guidelines, including which imaging modalities (eg, computed tomography [CT], magnetic resonance imaging [MRI], radiograph [XR], ultrasound [US]) that were discussed can be found in Supplemental Appendix 4.

A guideline is intended to guide and not be an absolute rule. Medical care is complex and should be based on evidence, a clinician's expert judgment, the patient's circumstances, values, preferences, and resource availability. Not all imaging modalities are available in all clinical environments, particularly in rural or remote areas of Canada. Decisions about patient transfer, use of alternative imaging or serial clinical examination and observation can be complex and difficult. Therefore, the expected benefits of recommended imaging, risks of travel, patient preference, and other factors must be considered. The guideline recommendations are designed to assist the choice of imaging modality in situations where it is deemed clinically necessary to obtain imaging.

Recommendations do not always specify when contrast should or should not be used, as this may vary based on clinical presentation, regional practice preferences, preference of

the referring clinician, radiologist and/or the patient, and resource availability. However, where it is essential for diagnosis, the type of imaging that requires contrast is mentioned (e.g., CT pulmonary angiogram, coronary CT angiogram).

We reviewed relevant recommendations related to the 30 clinical/diagnostic scenarios previously published by radiology and specialty societies, including: the Canadian Association of Radiologists,[9] the American College of Cardiology/American Heart Association (ACC/AHA),[10-12] the American College of Cardiology/American Association for Thoracic Surgery/American Heart Association/American Society of Echocardiography/American Society of Nuclear Cardiology/Heart Rhythm Society/Society for Cardiovascular Angiography and Interventions/Society of Cardiovascular Computed Tomography/Society for Cardiovascular Magnetic Resonance/Society of Thoracic Surgeons (ACC/AATS/AHA/ASE/ASNC/ HRS/SCAI/SCCT/SCMR/STS),[13,14] the American College of Radiology (ACR),[15-26] the American College of Rheumatology/Vasculitis Foundation,[27,28] the American Heart Association/American College of Cardiology/American Society of Echocardiography/American College of Chest Physicians/Society for Academic Emergency Medicine/Society of Cardiovascular Computed Tomography/Society for Cardiovascular Magnetic Resonance (AHA/ACC/ASE/ACCP/ SAEM/SCCT/SCMR),[29,30] the American Heart Association/American College of Cardiology (AHA/ACC),[31,32] the American Heart Association/American College of Cardiology/Heart Failure Society of America (AHA/ACC/HFSA),[33,34] the American Society of Hematology (ASH),[35] the American Thoracic Society (ATS),[36] the Brazil guideline,[37] the British Society for Rheumatology (BSR),[38,39] the Canadian Cardiovascular Society/Canadian Heart Failure Society (CCS/CHFS),[40] the European Society of Cardiology (ESC),[41-45] the European League Against Rheumatism (EULAR),[46-48] the German Cardiac Society (DGK),[49] the Italian Society of Vascular and Endovascular Surgery (SICVE),[50] the Japanese Circulation Society (JCS),[51,52] the Japanese Circulation Society/Japanese Heart Failure Society (JCS/JHFS),[53] the Japanese Circulation Society/Japanese Society for Cardiovascular Surgery/Japanese Association for Thoracic Surgery/Japanese Society for Vascular Surgery (JCS/JSCS/JATS/JSVS),[54] the National Heart Foundation of Australia/Cardiac Society of Australia and New Zealand (NHFA/CSANZ),[55] the National Institute for Health and Care Excellence (NICE),[56-60] the Royal College of Radiologists (RCR),[61] the Societa Italiana per lo Studio delle Anomalie Vascolari (SISAV),[62] the Society for Vascular Surgery (SVS),[63] and the Thrombosis and Haemostasis Society of Australia and New Zealand (THSANZ).[64]

Recommendations are presented in 3 tables: Acute chest pain syndromes recommendations (Table 2), Chronic chest pain, pericardial syndromes, intracardiac/pericardial mass, and suspected valvular disease recommendations (Table 3), and Cardiomyopathy, aorta, venous thrombosis, and peripheral vascular disease recommendations (Table 4).

Table 2. Acute Chest Pain Syndromes Recommendations.

Clinical/Diagnostic Scenario and Recommendations
CV01. ACUTE CHEST PAIN SYNDROMES
CV01A. Acute coronary syndrome: ST elevation myocardial infarction (STEMI)[9,13,29,30,33,34,55-57,61]
In patients presenting with suspected acute coronary syndrome, imaging should be offered based on clinical results (ie, ECG and cardiac troponin).
1. In patients meeting criteria for STEMI (ie, ECG), we recommend **invasive coronary angiography** as the initial imaging modality (↑↑).
↳ **1.1** In cases of diagnostic uncertainty OR if immediate invasive coronary angiography is unavailable, we suggest **chest XR and bedside TTE/POCUS (if available)** to evaluate for other potential causes of chest pain, but this should not delay care (↑).
CV01B. Acute coronary syndrome: non-STEMI[9,13,29,30,41,51,56,57,61]
In patients presenting with suspected acute coronary syndrome, imaging should be offered based on clinical results (ie, ECG and cardiac troponin).
1. In patients with suspected non-STEMI, we recommend **chest XR** (to rule out other causes of chest pain) **and bedside TTE/POCUS** (if available, to evaluate for ventricular function and rule out pericardial effusion) as the initial imaging modalities (↑↑).
↳ **1.1** In higher-risk patients, we recommend **invasive coronary angiography** as the next imaging modality (↑↑).
↳ **1.2** In lower-risk patients, we recommend **invasive coronary angiography or CCTA** as the next imaging modality, depending on clinical parameters (↑↑).

(continued)

Table 2. (continued)

Clinical/Diagnostic Scenario and Recommendations

CV01C. Acute coronary syndrome: unstable angina[9,13,29,30,56,57,61]

In patients presenting with suspected acute coronary syndrome, imaging should be offered based on clinical results (ie, ECG and cardiac troponin).

1. In patients with suspected unstable angina (ie, negative cardiac troponin), we recommend **chest XR** (to rule out other causes of chest pain) **and bedside TTE/POCUS** (if available, to evaluate for ventricular function and rule out pericardial effusion) as the initial imaging modalities (↑↑).
   - ↳ **1.1** For assessment of coronary artery disease and for risk stratification, we recommend **CCTA** (↑↑).

     Depending on regional practice preference and availability, stress echocardiography and NM (stress perfusion) may be considered. Internal medicine/cardiology consultation may also be considered.
2. In patients with suspected unstable angina with ongoing chest pain not relieved with medical management, we recommend **invasive coronary angiography** (↑↑).

CV01D. Acute aortic syndrome (including aortic dissection, intramural haematoma, and penetrating atherosclerotic ulcer)[9,10,13,15,29,30,61]

1. For patients with suspected acute aortic syndrome, we recommend **CTA** (preferably cardiac-gated, if available) as the initial imaging modality (↑↑).
   - ↳ **1.1** If CTA is contraindicated, we recommend **TEE or MRA** as alternative imaging modalities (↑↑).

CV01E. Pulmonary embolism[9,13,16,29,30,35,42,58,61]

Acute pulmonary embolism

1. In patients with suspected pulmonary embolism with low or intermediate pretest probability (as determined by a structured risk assessment tool) with a negative D-dimer, we recommend **against CTA/MRA/VQ scan** (↓↓).
2. In patients with suspected pulmonary embolism with low or intermediate pretest probability (as determined by a structured risk assessment tool) with a positive D-dimer test, we recommend **CT pulmonary angiography (CTPA)** as the initial imaging modality (↑↑).
   - ↳ **2.1** If immediate CTPA is not available, we recommend **chest XR** as the next imaging modality to exclude other causes of chest pain (↑↑).
   - ↳ **2.2** If CT pulmonary angiography is contraindicated, we suggest **VQ scan or MR pulmonary angiography** as an alternative (↑). [see *recommendation 4 for pregnant patients*]
3. In patients with suspected pulmonary embolism and high pretest probability (as determined by a structured risk assessment tool) or in patients with recurrent pulmonary embolism, we recommend **CTPA** as the initial imaging modality (↑↑).
   - ↳ **3.1**If immediate CTPA is not available, we recommend **chest XR** as the next imaging modality to exclude other causes of chest pain (↑↑).
   - ↳ **3.2** If CT pulmonary angiography is contraindicated, we suggest **VQ scan or MR pulmonary angiography** as an alternative (↑). [see *recommendation 4 for pregnant patients*]
4. For pregnant patients with high pretest probability (as determined by a structured risk assessment tool) of pulmonary embolism, we recommend **chest XR** as the initial imaging modality (↑↑).
   - ↳ **4.1** If chest XR does not explain the clinical presentation and further imaging is required, we recommend **Doppler US** as the next imaging modality (↑↑).
     - ↳ **4.2** If Doppler US is negative, we recommend **CTPA or NM (VQ scan)** as the next imaging modality (↑↑).

       In pregnant patients with a high pre-test probability of pulmonary embolism, and normal leg dopplers, some guidelines suggest performing V/Q scan. In practice, however, its availability is limited. CTPA is widely available, has better interobserver agreement, and ability to provide alternative diagnoses for acute chest pain presentation that support its use for evaluation of acute pulmonary embolism in pregnant patients. Mean maternal and foetal radiation dose is typically lower for reduced dose NM perfusion scanning (ie, no ventilation scanning performed) and breast radiation dose is typically higher with CTPA.

Note: MRI is not recommended for evaluation of pulmonary embolism in pregnant patients because gadolinium should be avoided in pregnant patients.[65]

Chronic pulmonary embolism

5. In patients with pulmonary hypertension suspected to be secondary to chronic thromboembolic disease (CTEPH), we recommend **VQ scan** as the initial imaging modality (EP consensus).
   - ↳ **5.1** If VQ scan is non-diagnostic, indeterminate for chronic pulmonary embolism, or unavailable, we recommend **CTPA** as an alternative (EP consensus).

     Dual energy CT technology or iodine subtraction maps can increase CTPA sensitivity to detect chronic pulmonary embolism.

(continued)

Table 2. (continued)

Clinical/Diagnostic Scenario and Recommendations
CV01F. Acute myocarditis[17,29,30,61]
1. In patients with suspected acute myocarditis, we recommend **TTE followed by cardiac MRI** as the initial imaging modalities (↑↑).
↳ **1.1** If cardiac MRI does not demonstrate acute myocarditis and if invasive coronary angiography has not been performed, we suggest **CCTA** as the next imaging modality to exclude obstructive coronary artery disease (↑) in appropriately selected patients.
CV01G. Acute pericarditis[9,17,18,29,30,61]
1. In patients with suspected acute pericarditis, we recommend **bedside TTE/POCUS or TEE** as the initial imaging modality to assess presence of pericardial thickening, effusion, as well as ventricular function and constrictive physiology (↑↑).
↳ **1.1** If further imaging is required to guide management (ie, pericardiocentesis), we suggest **CT** (preferably cardiac-gated, if available) as the next imaging modality (↑).
↳ **1.2** If TTE is inconclusive regarding acute pericarditis or constrictive physiology, we suggest **cardiac MRI** as an alternative (↑).
CV01H. Non-cardiac chest pain
See the scenarios in the CAR Thoracic Diagnostic Imaging Referral Guideline[66]: – TH02. Non-specific chest pain – TH14. Suspected pneumothorax (non-traumatic) – TH15. Clinically suspected pleural effusion

Note. Strength of recommendation: ↑↑ = strong for; ↑ = conditional for; ↓ = conditional against; ↓↓ = strong against. EP = Expert Panel; CCTA = coronary computed tomography angiography; CT = computed tomography; CTA = computed tomography angiography; CTPA = computed tomography pulmonary angiography; ECG = electrocardiography; MR = magnetic resonance; MRA = magnetic resonance angiography; MRI = magnetic resonance imaging; NM = nuclear medicine; POCUS = point of care ultrasound; STEMI = ST elevation myocardial infarction; TEE = transesophageal echocardiograph; TTE = transthoracic electrocardiograph; VQ scan = ventilation/perfusion scan; US = ultrasound; XR = radiograph.

Table 3. Chronic Chest Pain, Pericardial Syndromes, Intracardiac/Pericardial Mass, and Suspected Valvular Disease Recommendations.

Clinical/Diagnostic Scenario and Recommendations
CV02. CHRONIC CHEST PAIN
CV02A. Suspected chronic ischaemic heart disease[9,13,19,29,30,33,34,43,44,51,55,61]
1. In patients *with established chronic ischaemic heart disease* with recurrent chest pain symptoms despite guideline directed medical therapy and intermediate risk/pre-test probability or known non-obstructive CAD, we suggest **anatomical (CCTA), functional (stress NM, stress echo) imaging, or stress MR** as the initial imaging modalities (↑).
↳ **1.1** To identify patients who may benefit from further investigation with invasive coronary angiography, we suggest **CT-fractional flow reserve (CT-FFR)** (↑).
2. In patients *with established chronic ischaemic heart disease* with recurrent chest pain symptoms despite guideline directed medical therapy and high risk/pre-test probability, we recommend **invasive coronary angiography** as the initial imaging modality (↑↑).
3. In patients *with established chronic ischaemic heart disease* with prior coronary revascularization with percutaneous coronary intervention (PCI) or coronary artery bypass grafts (CABG) and with recurrent chest pain symptoms, we suggest **CCTA** to evaluate for stent (especially if stent > 3mm) or graft patency (↑).
↳ **3.1** If evaluation for ischaemia to account for symptoms is important, we recommend **NM (myocardial perfusion scan)** (↑↑).
4. In patients with stable chest pain *without established ischaemic heart disease* presenting to the outpatient clinic and at low risk/pre-test likelihood of having obstructive CAD (as determined by a structured assessment tool), **routine imaging investigations** are not recommended (↓↓).
↳ **4.1** In selected patient populations, we suggest **calcium score CT** (for excluding calcified plaque and identifying patients at low likelihood of obstructive CAD) or **exercise ECG** testing (↑).
5. In patients *without established chronic ischaemic heart disease* with recurrent stable chest pain symptoms and intermediate or high risk/pre-test probability, we recommend **CCTA** for diagnosis of CAD, risk prognostication and guiding of treatment decisions (↑↑).
↳ **5.1** For diagnosis of myocardial ischaemia and estimation of risk of major adverse cardiovascular events (MACE), we recommend **functional imaging (stress echocardiography or PET/SPECT MPI or CMR)** (↑↑).

(continued)

Table 3. (continued)

Clinical/Diagnostic Scenario and Recommendations

CV02B. Non-cardiac chest pain

See the scenarios in the CAR Thoracic Diagnostic Imaging Referral Guideline[66]:

– TH02. Non-specific chest pain

– TH15. Clinically suspected pleural effusion

CV03. cardiovascular screening and risk stratification (calcium score CT)[61]

1. In asymptomatic low-risk adults, we suggest **against routine cardiovascular imaging screening and risk stratification** (↓).
2. In asymptomatic intermediate-risk adults, we recommend **calcium score CT** for optimal risk stratification to guide medical management (↑↑).

   In high-risk patients reluctant to initiate optimal medical management, calcium score CT can provide useful information for patient counselling.

CV04. Pericardial syndromes

CV04A. Acute pericarditis

See CV01G. Acute chest pain syndromes: Acute pericarditis in Table 2.

CV04B. Pericardial effusion[9,13,61]

1. In patients with suspected pericardial effusion, we recommend **TTE** as the initial imaging modality (↑↑).
   - ↳ **1.1** If there is suspected effusive constrictive/constrictive physiology, we suggest **CT** (preferably cardiac-gated, if available) as the next imaging modality to evaluate for pericardial thickness, pericardial effusion, and calcification (↑).
     - ↳ **1.2** If TTE is inconclusive for effusive constrictive/constrictive physiology, we recommend **cardiac MRI** as the next imaging modality (↑↑).
       - ↳ **1.3** If cardiac MRI is inconclusive for effusive constrictive/constrictive physiology, we recommend **cardiac catheterization** (↑↑).

CV04C. Constrictive pericarditis[13,61]

1. In patients with suspected constrictive pericarditis, we recommend **TTE** as the initial imaging modality (↑↑).
   - ↳ **1.1** If there is suspected constrictive physiology, we suggest **CT** (preferably cardiac-gated, if available) as the next imaging modality to evaluate for pericardial thickness and calcification (↑).
     - ↳ **1.2** If TTE is inconclusive for constrictive physiology, we recommend **cardiac MRI** as the next imaging modality (↑↑).
       - ↳ **1.3** If cardiac MRI is inconclusive for constrictive physiology, we recommend **cardiac catheterization** (↑↑).

CV05. Intracardiac/pericardial mass

CV05A. Normal variant[13]

1. In patients with a suspected intracardiac or pericardial mass (versus normal variant) detected on chest CT, we recommend **TTE** as the initial imaging modality (↑↑).
   - ↳ **1.1** If further imaging is required, we recommend **cardiac MRI** as the next imaging modality (↑↑).
     - ↳ **1.2** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality (↑↑).
2. In patients with a suspected intracardiac or pericardial mass (versus normal variant) incidentally detected on TTE, we recommend **cardiac MRI** for further characterization (↑↑).
   - ↳ **2.1** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as the next imaging modality (↑↑).

CV05B. Masses[13]

1. In patients with intracardiac or pericardial mass detected on chest CT, we recommend **TTE** as the initial imaging modality (↑↑).
   - ↳ **1.1** If further imaging is required, we recommend **cardiac MRI** as the next imaging modality (↑↑).
     - ↳ **1.2** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality (↑↑).
2. In patients with intracardiac or pericardial mass detected on TTE, we recommend **cardiac MRI** for further characterization (↑↑).
   - ↳ **2.1** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as the next imaging modality (↑↑).

   Cardiac PET may be helpful to guide management.

(continued)

Table 3. (continued)

Clinical/Diagnostic Scenario and Recommendations

CV06. Suspected valvular disease

CV06A. Aortic valve[9,11-14,18,20,54,61]

Aortic stenosis

1. In patients with suspected aortic valve stenosis, we recommend **TTE** as the initial imaging modality (↑↑).

- ↳ **1.1** If the severity of the aortic valve stenosis is unclear (eg, in suspected low flow low gradient severe aortic valve stenosis), we recommend **calcium score CT of the aortic valve** as the next imaging modality (↑↑).
- ↳ **1.2** In patients with suspected aortic valve stenosis where pulmonary oedema is suspected, we recommend **chest XR** as the next imaging modality (↑↑).

Aortic regurgitation

2. In patients with suspected aortic valve regurgitation, we recommend **TTE** as the initial imaging modality (↑↑).

- ↳ **2.1** If further imaging is required due to poor acoustic windows or if information about ventricular size and function is required, we recommend **cardiac MRI** as the next imaging modality (↑↑) or **TEE** if the mechanism or severity of aortic valve regurgitation is unclear.
  - ↳ **2.2** If MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality for evaluation of ventricular size and function (↑↑).
- ↳ **2.3** In patients with suspected aortic valve regurgitation where pulmonary oedema is suspected, we recommend **chest XR** as the next imaging modality (↑↑).

Infective endocarditis—native valve

3. After completing TTE for aortic valve disease, we recommend **TEE** for suspected infective endocarditis, to further characterize stenosis severity or mechanism of regurgitation, and for ruling out aortic root abscess (↑↑).

- ↳ **3.1** If there is concern for aortic root abscess and TEE is contraindicated, we recommend **cardiac CT** (↑↑).

Infective endocarditis—prosthetic valve

4. In patients with prosthetic valve, we recommend **TTE and TEE** for suspected infective endocarditis, to further characterize stenosis severity or mechanism of regurgitation, and for ruling out aortic root abscess (↑↑).

- ↳ **4.1** If there is concern for aortic root abscess and TEE is contraindicated, we recommend **cardiac CT** (↑↑).

CV06B. Mitral valve[9,11,12,14,18,20,54,61]

These recommendations are to guide diagnostic imaging of the mitral valve and does not include imaging to guide interventions.

Mitral stenosis

1. In patients with suspected mitral valve stenosis, we recommend **TTE** as the initial imaging modality (↑↑).

- ↳ **1.1** If intervention is contemplated or required, we recommend **TEE** as the next imaging modality (↑↑).

2. In patients with suspected mitral valve stenosis where pulmonary oedema is suspected, we recommend **chest XR** as the next imaging modality (↑↑).

Mitral regurgitation

3. In patients with suspected mitral valve regurgitation, we recommend **TTE** as the initial imaging modality (↑↑).

- ↳ **3.1** If the mechanism or severity is unclear on TTE, we recommend **TEE** as the next imaging modality (↑↑).
  - ↳ **3.2** If further imaging is required due to poor acoustic windows OR if information about ventricular size and function or confirmation of mitral regurgitation severity is required, we recommend **cardiac MRI** as the next imaging modality (↑↑).

4. In patients with suspected mitral valve regurgitation where pulmonary oedema is suspected, we recommend **chest XR** as the next imaging modality (↑↑).

CV06C. Pulmonary valve[9,11,12,14,18,20,54,61]

1. In patients with suspected pulmonary valve disease, we recommend **TTE** as the initial imaging modality (↑↑).

- ↳ **1.1** If further imaging is required due to poor acoustic windows or if information about ventricular size and function is required (eg, tetralogy of Fallot), we recommend **cardiac MRI** as the next imaging modality (↑↑).
  - ↳ **1.2** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality (↑↑).

(continued)

Table 3. (continued)

Clinical/Diagnostic Scenario and Recommendations
2. After completing TTE for pulmonary valve disease, we suggest **TEE** for suspected infective endocarditis, to further characterize stenosis severity or mechanism of regurgitation, and for ruling out abscess (↑).
3. In patients with suspected pulmonary valve disease where supra and sub-valvular pathologies are possible based on TTE findings, we recommend **cardiac MRI** as the next imaging modality (↑↑).
↳ **3.1** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality (↑↑).
CV06D. Tricuspid valve[9,11,12,14,18,20,54,61]
1. In patients with suspected tricuspid valve disease, we recommend **TTE** as the initial imaging modality (↑↑).
↳ **1.1** If further imaging is required due to poor acoustic windows or if information about ventricular size and function is required, we recommend **cardiac MRI** as the next imaging modality (↑↑).
↳ **1.2** If cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** as an alternative imaging modality (↑↑).
2. After completing TTE for tricuspid valve disease, we suggest **TTE** for suspected infective endocarditis, to further characterize stenosis severity or mechanism of regurgitation, and for ruling out abscess (↑).

Note. Strength of recommendation: ↑↑ = strong for; ↑ = conditional for; ↓ = conditional against; ↓↓ = strong against. EP = Expert Panel; CAD = coronary artery disease; CCTA = coronary computed tomography angiography; CMR = cardiac magnetic resonance; CT = computed tomography; ECG = electrocardiogram; MR = magnetic resonance; MRI = magnetic resonance imaging; NM = nuclear medicine; PET = positron emission tomography; SPECT MPI = single-photon emission computed tomography myocardial perfusion imaging; TEE = transesophageal electrocardiography; TTE = transthoracic electrocardiography; XR = radiograph.

Table 4. Cardiomyopathy, Aorta, Venous Thrombosis, and Peripheral Vascular Disease Recommendations.

Clinical/Diagnostic Scenario and Recommendations
CV07. CARDIOMYOPATHY
CV07A. Cardiomyopathy: dilated[9,13,17,45,53]
1. In patients with suspected dilated cardiomyopathy, we recommend **TTE** as the initial imaging modality (↑↑).
↳ **1.1** If ischaemic dilated cardiomyopathy is a possibility, we recommend **invasive catheter angiography** for further evaluation (↑↑).
↳ **1.2** If invasive catheter angiography is unavailable, we recommend **CCTA** as an alternative (↑↑).
↳ **1.3** If there is no significant obstructive coronary artery disease based on invasive catheter angiography or CCTA results and further imaging is required, we recommend **cardiac MRI** as the next imaging modality (↑↑).
↳ **1.4** If information about ventricular size and function is required (and if ventricular size/function is unreliable by TTE) and cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** (↑↑).
↳ **1.5** If cardiac CT is not available, we suggest **NM (MUGA)** (↑). *NM (myocardial perfusion scan) may also be helpful to exclude significant ischaemia as a cause of dilated cardiomyopathy.*
CV07B. Cardiomyopathy: hypertrophic[9,13,17,31,32,45,53]
1. In patients with suspected hypertrophic cardiomyopathy, we recommend **TTE** as the initial imaging modality (↑↑).
↳ **1.1** If further imaging is required✧, we recommend **cardiac MRI** as the next imaging modality (↑↑).
↳ **1.2** If information about ventricular size and function or maximum wall thickness is required AND cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** (↑↑).
↳ **1.3** To rule out obstructive coronary artery disease as a cause of symptoms, we recommend **invasive catheter angiography** (↑↑) in carefully selected patients.
↳ **1.4** If invasive catheter angiography is unavailable, we recommend **CCTA** as an alternative (↑↑).
✧MRI can be helpful when echocardiography is inconclusive, when other diagnoses are possible (eg, amyloidosis, athlete's heart, storage disease, etc.), or when information about maximum wall thickness, ejection fraction, presence of apical aneurysm or extent of late gadolinium enhancement will influence decision to insert an implantable cardioverter-defibrillator (ICD).

(continued)

Table 4. (continued)

Clinical/Diagnostic Scenario and Recommendations
CV07C. Cardiomyopathy: restrictive[9,13,17,36,40,45,49,52]
1. In patients with suspected restrictive/infiltrative cardiomyopathy, we recommend **TTE** as the initial imaging modality (↑↑). ↳ **1.1** If further imaging is required, we recommend **cardiac MRI** as the next imaging modality (↑↑). ↳ **1.2** If information about ventricular size and function is required and cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** (↑↑). ↳ **1.3** In patients with suspected cardiac sarcoidosis, we recommend **FDG-PET-CT** (↑↑). ↳ **1.4** In patients with suspected cardiac amyloidosis, if further imaging is required, we recommend **NM (pyrophosphate scan)** as the next imaging modality (↑↑).
CV07D. Cardiomyopathy: arrhythmogenic[9,13,17,45]
1. In patients with suspected arrhythmogenic cardiomyopathy, we recommend **TTE** as the initial imaging modality (↑↑). ↳ **1.1** If further imaging is required, we recommend **cardiac MRI** as the next imaging modality (↑↑). ↳ **1.2** If information about ventricular size and function is required and cardiac MRI is not tolerated, is unavailable, or is contraindicated, we recommend **cardiac CT** (↑↑). ↳ **1.3** If obstructive coronary artery disease needs to be ruled out as the cause for arrhythmia, we recommend **invasive catheter angiography** (↑↑). ↳ **1.4** If invasive catheter angiography is unavailable, we recommend **CCTA** as an alternative (↑↑).
CV08. Aorta
CV08A. Thoraco-abdominal aneurysm[9,10,13,21,50,58,61,63]
1. In patients with thoracic aortic aneurysm identified by TTE, we recommend **chest CTA** (preferably cardiac-gated) for baseline measurement and surveillance (↑↑). *In younger patients with thoraco-abdominal aortic aneurysm identified by TTE, MRA may be performed for baseline measurement and surveillance. Surgical consultation could be considered for aortas >4.5 cm in size.* **2.** In patients without underlying aortopathy with suspected abdominal aortic aneurysm (AAA) based on physical examination, we recommend **US** as the initial imaging modality (↑↑). ↳ **2.1** If US demonstrates aortic diameter between 2.5 and 3.0 cm, we suggest re-evaluation with **US** after 10 years (↑↑). ↳ **2.2** If US demonstrates aortic diameter between 3.0 and 3.9 cm, we recommend repeat **US** at 3-year intervals (↑↑). ↳ **2.3** If US demonstrates aortic diameter between 4.0 and 4.9 cm, we recommend annual surveillance with **US or CT** (↑↑). *Surgical consultation could be considered for aortas >4.5 cm in size.* For detailed recommendations for patients with underlying aortopathies and sex specific recommendations, see ACC/AHA guideline.[10] **3.** In patients with symptoms suspected to be related to thoraco-abdominal aneurysm, we recommend **CT with contrast** (↑↑).
CV08B. Vasculitis[22,27,38,39,46-48]
1. In patients with suspected vasculitis involving the aorta (ie, aortitis), we recommend **MRA** for baseline measurement and surveillance, especially in young patients (↑↑). ↳ **1.1** If MRA is not tolerated, is unavailable, or is contraindicated, we recommend **CTA** for baseline measurement and surveillance (↑↑). ↳ **1.2** If MRA or CTA results are inconclusive regarding disease activity, we suggest **FDG-PET-CT or MR-PET** (↑).
CV09. Venous thrombosis[9,23,24,35,37,59-61,64]
1. In patients with suspected deep vein thrombosis with low pre-test probability (as determined by a structured risk assessment tool) AND negative D-dimer, we recommend **no imaging** (↓↓). ↳ **1.1** If D-dimer is unavailable, we recommend **interim therapeutic anticoagulation and Doppler US** (↑↑). ↳ **1.2** If US is inconclusive or of poor quality and further imaging is required, we recommend **CTV or MRV** as the next imaging modality, with preference for MRV in younger patients (↑↑). **2.** In patients with suspected deep vein thrombosis based with intermediate/high pre-test probability (as determined by a structured risk assessment tool) and/or positive D-dimer, we recommend **Doppler US** as the initial imaging modality (↑↑). **3.** In patients with superficial venous thrombosis, we suggest **Doppler US** as the initial imaging modality (↑).

(continued)

Table 4. (continued)

Clinical/Diagnostic Scenario and Recommendations
CV10. Peripheral vascular disease
CV10A. Upper and lower extremity peripheral vascular disease[9,22,25,28,61]
1. In patients with suspected upper or lower extremity peripheral vascular (arterial) disease based on symptoms or other clinical features and an abnormal ankle-brachial index (ABI $<$ 0.9), we recommend **Doppler US** for further evaluation (↑↑). ↳ **1.1** If further imaging is required, we recommend **CTA or MRA** as the next imaging modality (↑↑). **2.** In patients with established upper or lower extremity peripheral vascular (arterial) disease with recurrent symptoms, we recommend **CTA or MRA** as the initial imaging modality (↑↑).
CV10B. Vascular malformation[26,62]
1. In patients with suspected vascular malformation, to further characterize and guide further management, we recommend **time-resolved MRA** as the initial imaging modality (↑↑). *In patients presenting with an extremity mass and suspected vascular malformation,* ***Doppler US*** *could be performed as the initial test.* ↳ **1.1** If MRA is not tolerated, is unavailable, or is contraindicated, we recommend **CTA** as an alternative (↑↑). ↳ **1.2** To guide further management for high flow vascular malformations, we recommend **invasive catheter angiography** (↑↑).
CV10C. Entrapment and compression syndrome[25]
1. In patients with entrapment and compression syndromes involving the extremities where venous thrombosis is also of concern, we recommend **Doppler US** as the initial imaging modality (↑↑). ↳ **1.1** If Doppler US is negative or indeterminate and additional imaging is required, we recommend **MRA** as the next imaging modality (↑↑). ↳ **1.2** If MRA is not tolerated, is unavailable, or is contraindicated, we recommend or **CTA** as an alternative (↑↑).

Note. Strength of recommendation: ↑↑ = strong for; ↑ = conditional for; ↓ = conditional against; ↓↓ = strong against. EP = Expert Panel; CCTA = coronary computed tomography angiography; CT = computed tomography; CTA = computed tomography angiography; CTV = computed tomography venography; FDG-PET-CT = fluorodeoxyglucose-positron emission tomography computed tomography; MR-PET = magnetic resonance-positron emission tomography; MRA = magnetic resonance angiography; MRI = magnetic resonance imaging; MRV = magnetic resonance venography; MUGA = multigated acquisition scan; NM = nuclear medicine; TTE = transthoracic electrocardiography; US = ultrasound.

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Supplemental Material

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