Role of imaging in acute cardiovascular care

Tatiana Guimarães
Department of Cardiology, Santa Maria University Hospital, CHLN
Center of Cardiology of the University of Lisbon (CCUL), Faculty of Medicine
Lisbon Academic Medical Center
Lisboa, Portugal
Imaging techniques in acute cardiovascular care

- **Chest X-ray**

- **Ultrasound**
  - Echocardiography (TT/TE)
  - Thoracic
  - Vascular

- **Computed tomography angiography**
  - Coronary
  - Pulmonary
  - Aorta

- **Cardiac magnetic resonance**

- Diagnosis
- Treatment decisions
- Follow up
- Prognostic stratification
## Imaging techniques in acute cardiovascular care

<table>
<thead>
<tr>
<th></th>
<th>Main applications</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chest X-ray</strong></td>
<td>Diagnosis of HF</td>
<td>Low specificity</td>
</tr>
<tr>
<td></td>
<td>Diagnosis of concurrent extracardiac disease (pneumothorax, pleural effusion, consolidation, etc.)</td>
<td>Limited correlation with hemodynamic parameters</td>
</tr>
<tr>
<td><strong>Focused TTE</strong></td>
<td>Global assessment of cardiac structure and function in acute situations</td>
<td>Equipment technically inferior</td>
</tr>
<tr>
<td></td>
<td>Qualitative assessment of:</td>
<td>Specific training</td>
</tr>
<tr>
<td></td>
<td>• Pericardial effusion</td>
<td>Stressful situations</td>
</tr>
<tr>
<td></td>
<td>• Intravascular volume</td>
<td>Risk of missing important abnormalities</td>
</tr>
<tr>
<td></td>
<td>• Ventricular size and function</td>
<td>Window</td>
</tr>
<tr>
<td></td>
<td>Pulmonary ultrasound</td>
<td></td>
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<tr>
<td><strong>Comprehensive TTE</strong></td>
<td>Syndromic diagnosis (preserved vs reduced LVEF)</td>
<td>Specific training</td>
</tr>
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<td></td>
<td>Etiological diagnosis (ischemia, valvular heart disease, cardiomyopathies, etc.)</td>
<td>Window</td>
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<tr>
<td></td>
<td>Noninvasive hemodynamic assessment</td>
<td></td>
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<tr>
<td><strong>TEE</strong></td>
<td>As with TTE</td>
<td>Adequate training</td>
</tr>
<tr>
<td></td>
<td>Endocarditis, intracardiac thrombus, aortic dissection</td>
<td>Esophageal probing</td>
</tr>
<tr>
<td></td>
<td>Valvular heart disease (severity and mechanism)</td>
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<tr>
<td></td>
<td>Monitoring of therapeutic procedures</td>
<td></td>
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<td></td>
<td>Possibility of continuous monitoring (miniaturized probes)</td>
<td></td>
</tr>
<tr>
<td><strong>CT</strong></td>
<td>Triple rule out: noninvasive coronary angiography, pulmonary thromboembolism, acute aortic syndrome</td>
<td>Radiation</td>
</tr>
<tr>
<td></td>
<td>Diagnosis of concurrent pulmonary and chest disease</td>
<td>Iodinated contrast (hypersensitivity, nephrotoxicity)</td>
</tr>
<tr>
<td><strong>MRI</strong></td>
<td>Characterization of myocardium</td>
<td>Hemodynamic instability, metallic implants, devices, etc.</td>
</tr>
<tr>
<td></td>
<td>Quantification of severity of valvular heart disease</td>
<td>Availability</td>
</tr>
<tr>
<td></td>
<td>Aortography</td>
<td>Gadolinium contrast</td>
</tr>
</tbody>
</table>

CT, computed tomography; HF, heart failure; LVEF, left ventricular ejection fraction; MRI, magnetic resonance imaging; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography.
Imaging techniques in acute cardiovascular care

- **Chest X-ray**
  - Diagnosis and follow up
  - Device placements

  ❌ Radiation exposure
  ❌ Low specificity
  ❌ Limited correlation with hemodynamic parameters
Imaging techniques in acute cardiovascular care

- **Chest X-ray**
  - Diagnosis and follow up

**Water retention-related problems**

[Images: Right-sided pleural effusion and Pericardial effusion]

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**Chest X-ray**
- Diagnosis and follow up

**Air-related problems**

(A) Subcutaneous emphysema. (B) Large bilateral tension pneumothorax. (C) Pneumomediastinum. (D) Pneumopericardium.
Imaging techniques in acute cardiovascular care

- **Chest X-ray**
  - Diagnosis and follow up

### Lung-related problems

- **Pneumonia** (opacity in right lower lobe)
- **Massive PE** (enlargement of the right pulmonary artery - Palla’s sign), oligaemia of pulmonary vessels (Westmark’s sign)
- **Pulmonary oedema** (bat wing opacities, Kerley A lines running to the periphery)

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**Chest X-ray**
- Diagnosis and follow up

**Lung-related problems**

ARDS (bilateral airspace opacities and increased interstitial markings in a patient with acute respiratory failure)

Aspiration pneumonia (right lower lobe consolidation, right-sided pulmonary oedema)

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- Chest X-ray
  - Device placements
    - **Endotracheal tubes**
    - Central venous catheters
    - IABPs
    - Pacemakers leads
    - Chest Tubes and drains

Correctly placed ETT
Imaging techniques in acute cardiovascular care

- **Chest X-ray**
  - Device placements
    - Endotracheal tubes
    - **Central venous catheters**
    - IABP
    - Pacemakers leads
    - Chest Tubes and drains
**Chest X-ray**  
- Device placements
  - Endotracheal tubes  
  - Central venous catheters  
  - **IABP**  
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**Chest X-ray**
- Device placements
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**Imaging techniques in acute cardiovascular care**

**Chest X-ray**
- Device placements
  - Endotracheal tubes
  - Central venous catheters
  - IABP
  - Pacemakers leads
  - **Chest Tubes and drains**

Partial resolution of right-sided pneumothorax after chest tube placement
Imaging techniques in acute cardiovascular care

- **Ultrasound**
- **Echocardiography vs FoCUS**

![Diagram showing echocardiography and FoCUS levels with descriptions.](image)

Cholley et al. 2006; Price et al., 2008
Imaging techniques in acute cardiovascular care

- **Ultrasound FoCUS**
  - Standardized and restricted, scanning protocol
  - Extension of the clinical examination
  - To detect a limited number of critical cardiac conditions
  - Immediate decisions

Focus cardiac ultrasound core curriculum and core syllabus of the European Association of Cardiovascular Imaging

Nescovik et al., EHJ. 2018

Tatiana Guimarães, Santa Maria University Hospital, Lisboa, Portugal
## Ultrasound FoCUS

<table>
<thead>
<tr>
<th>Aetiology</th>
<th>Key echocardiographic signs</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV pump failure</td>
<td>Enlarged hypokinetic, spheroid LV, functional mitral regurgitation</td>
<td></td>
</tr>
<tr>
<td>Pulmonary embolism (PE)</td>
<td>Enlarged RV apex reaching cardiac apex, hypokinetic RV, tricuspid regurgitation, elevated pulmonary pressure (degree varies with pre-existing pulmonary hypertension (PH), RV function, and extent of embolism)</td>
<td></td>
</tr>
<tr>
<td>Pericardial tamponade</td>
<td>Pericardial fluid compressing the RV and/or right atrium; exaggerated respiratory variation in LV and RV inflow</td>
<td>Look for signs of aortic dissection, MI, trauma, or other thoracic disease, e.g. tumours</td>
</tr>
<tr>
<td>Acute left-sided valvular regurgitation</td>
<td>Structural damage of aortic or mitral valve, e.g. papillary muscle rupture; Doppler signs of severe aortic or mitral regurgitation; hyperkinetic LV, often of normal size</td>
<td>Look for signs of inferior MI in papillary muscle rupture and for signs of aortic dissection in aortic regurgitation</td>
</tr>
<tr>
<td>Acute right heart failure</td>
<td>Enlarged hypokinetic RV, may occur with PE, chronic PH, or as RV infarction complicating inferior myocardial infarction (MI)</td>
<td></td>
</tr>
<tr>
<td>Aortic dissection or rupture</td>
<td>Aortic enlargement, aortic valvular regurgitation, dissection flap in the aorta, pericardial tamponade</td>
<td>The typical site of aortic rupture, e.g. after deceleration trauma, is the proximal descending aorta, which is visualizable by TOE</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Endocarditic vegetation on valve or pacemaker electrode, abscess, or destruction of valves</td>
<td>In sepsis due to non-cardiac causes, the discrepancy between systemic hypotension in the presence of an often hyperkinetic heart is typical</td>
</tr>
<tr>
<td>Prosthetic valve obstruction</td>
<td>Frozen’ occluder position in mitral prostheses, often with clear thrombus in the aortic position, difficult to see, even by TOE. Massive transvalvular gradient elevation by Doppler</td>
<td>Always use TOE, compare to earlier transprosthetic gradients, if possible</td>
</tr>
<tr>
<td>Prosthetic valve regurgitation or dehiscence</td>
<td>Abnormal mobility (‘rocking’) of prosthesis (colour) Doppler signs of severe regurgitation, premature mitral valve closure in aortic regurgitation</td>
<td>Continuity equation must be used to evaluate stenosis severity; gradients may be deceptively low</td>
</tr>
</tbody>
</table>

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Imaging techniques in acute cardiovascular care

- **Ultrasound FoCUS**
  - ✗ Time-constrains
  - ✗ Restricted image acquisition protocol
    - ✗ Risk of missing important abnormalities
    - ✗ Operator experience
  - ✗ Technic equipment technically inferior
  - ✗ Stressful situations

**Focus cardiac ultrasound core curriculum and core syllabus of the European Association of Cardiovascular Imaging**

Nescovik et al., EHJ. 2018

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Ultrasound FoCUS

- Lung ultrasound
  - pulmonar edema
  - pleural effusion
  - pneumothorax

Interstitial pulmonary edema (B lines)
Ultrasound FoCUS

- Lung ultrasound
  - pulmonar edema
  - pleural effusion
  - pneumothorax

Pleural effusion
Imaging techniques in acute cardiovascular care

- **Ultrasound FoCUS**

  - Lung ultrasound
    - pulmonar edema
    - pleural effusion
    - pneumothorax

Normal lung will show a “seashore sign” with transition of lines differentiating movement at the pleural lines, whereas pneumothorax prevents detection of motion creating a single “bar code” pattern.
- Ultrasound FoCUS
  - Lung ultrasound

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**Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial**

Pivetta et al., EHJ. 2019
Ultrasound FoCUS

• Lung ultrasound

Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial

Conclusion

Integration of LUS with clinical assessment for the diagnosis of ADHF in the emergency department seems to be more accurate than the current diagnostic approach based on CXR and NT-proBNP.

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Ultrasound
Echocardiography vs FoCUS

Cholley et al. 2006; Price et al., 2008
Echocardiography in specific scenarios

Acute coronary syndromes – diagnosis

Universal definitions of myocardial injury and myocardial infarction

Criteria for myocardial injury

The term myocardial injury should be used when there is evidence of elevated cardiac troponin values (cTn) with at least one value above the 99th percentile upper reference limit (URL). The myocardial injury is considered acute if there is a rise and/or fall of cTn values.

Criteria for acute myocardial infarction (types 1, 2 and 3 MI)

The term acute myocardial infarction should be used when there is acute myocardial injury with clinical evidence of acute myocardial ischaemia and with detection of a rise and/or fall of cTn values with at least one value above the 99th percentile URL and at least one of the following:

- Symptoms of myocardial ischaemia;
- New ischaemic ECG changes;
- Development of pathological Q waves;
- Imaging evidence of new loss of viable myocardium or new regional wall motion abnormality in a pattern consistent with an ischaemic aetiology;
- Identification of a coronary thrombus by angiography or autopsy (not for types 2 or 3 MIs).

Post-mortem demonstration of acute athero-thrombosis in the artery supplying the infarcted myocardium meets criteria for type 1 MI. Evidence of an imbalance between myocardial oxygen supply and demand unrelated to acute athero-thrombosis meets criteria for type 2 MI. Cardiac death in patients with symptoms suggestive of myocardial ischaemia and presumed new ischaemic ECG changes before cTn values become available or abnormal meets criteria for type 3 MI.

Thygesen et al., EHJ. 2018
Echocardiography in specific scenarios

Acute coronary syndromes – complications and prognosis

| EMERGENTE | Choque cardiogénico  
|           | Instabilidade hemodinâmica  
|           | Suspeita de complicações mecânicas |
| ROTINA    | Avaliação da função ventricular  
|           | Prognóstico  
|           | Terapêutica  

Roffi et al., EHJ. 2016  
Ibanez et al., EHJ. 2018  

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Echocardiography in specific scenarios

Acute coronary syndromes – complications and prognosis

- Left ventricular dysfunction
- Right ventricle infarctation
- Trombus
- Aneurysms
- Mitral regurgitation
  - tethering
  - chordal rupture
  - papillary muscle rupture
- Ventricular septum defect
- Ventricular free wall rupture
Echocardiography in specific scenarios

Acute coronary syndromes – complications and prognosis
• Left ventricular dysfunction
Echocardiography in specific scenarios

**Acute coronary syndromes** – complications and prognosis
- RV infarction
Echocardiography in specific scenarios

Acute coronary syndromes – complications and prognosis

• Trombus
Echocardiography in specific scenarios

**Acute coronary syndromes** – complications and prognosis

- Mitral regurgitation (papillary muscle rupture)
Echocardiography in specific scenarios

**Acute coronary syndromes** – complications and prognosis
- Mitral regurgitation (leaflet thetering)
Imaging techniques in acute cardiovascular care

- Echocardiography in specific scenarios

  Acute coronary syndromes – complications and prognosis
  - Ventricular septum defect
Imaging techniques in acute cardiovascular care

- **Echocardiography in specific scenarios**

  **Acute coronary syndromes** – complications and prognosis
  - Pseudoaneurysm
Imaging techniques in acute cardiovascular care

- Echocardiography in specific scenarios
  
  Takotsubo syndrome
Echocardiography in specific scenarios

Heart Failure

- Systolic left ventricular function

**Ejection fraction:**
- Simpson biplane
- 3D
- Contrast

**Myocardial deformation**

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Echocardiography in specific scenarios

Journal of the American College of Cardiology

Volume 71, Issue 18, May 2018
DOI: 10.1016/j.jacc.2018.02.064

Global Longitudinal Strain to Predict Mortality in Patients With Acute Heart Failure
Jin Joo Park, Jun-Bean Park, Jae-Hyeong Park and Goo-Yeong Cho

GLS has greater prognostic value than LVEF
Imaging techniques in acute cardiovascular care

- Echocardiography in specific scenarios
  
  **Heart Failure**
  
  - Diastolic left ventricular function
  - Etiology
  - Mitral regurgitation
  - RV dysfunction
  - Prognosis
  - Treatment
**Echocardiography in specific scenarios**

**Heart Failure**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Level of evidence</th>
<th>Level of recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE is recommended for the assessment of myocardial structure and function in subjects with suspected HF in order to establish a diagnosis of either HFrEF, HFmrEF or HFpEF.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>TTE is recommended to assess LVEF in order to identify patients with HF who would be suitable for evidence-based pharmacological and device (ICD, CRT) treatment recommended for HFrEF.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>TTE is recommended for the assessment of valve disease, right ventricular function and pulmonary arterial pressure in patients with an already established diagnosis of either HFrEF, HFmrEF or HFpEF in order to identify those suitable for correction of valve disease.</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>TTE is recommended for the assessment of myocardial structure and function in subjects to be exposed to treatment which potentially can damage myocardium (e.g. chemotherapy).</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Other techniques (including systolic tissue Doppler velocities and deformation indices, i.e. strain and strain rate), should be considered in a TTE protocol in subjects at risk of developing HF in order to identify myocardial dysfunction at the preclinical stage.</td>
<td>IIa</td>
<td>C</td>
</tr>
</tbody>
</table>

*Ponikowski et al., EHJ. 2018*
Echocardiography in specific scenarios

Heart Failure

- Non-invasive hemodynamic assessment

Cardiac output

Volume status
- Central venous pressure (IVC and respiratory variation)
- LV filling pressures (E/e´)

Pulmonary pressures
- PSAP
Echocardiography in specific scenarios

Circulatory support therapies

- Candidate patients
- Type of support
- Optimization
- Widrawal or weaning
Echocardiography in specific scenarios

Circulatory support therapies

- ECMO V-A

Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock

Step 1: The etiology of cardiac failure must be compatible with myocardial recovery

Step 2: Hemodynamic stability:
- The patient should have recovered from major metabolic disturbances
- The patient should have recovered a pulsatile arterial waveform for at least 24 hours
- Baseline MAP > 60 mmHg in the absence or with low doses of catecholamine

Step 3: Pulmonary function should not be severely impaired
If PaO2/FiO2 < 100 mmHg when FiO2 of the ECMO gas flow is set at 21%, consider bridging the patient from VA- to VV-ECMO

Step 4: The patient must tolerate a full weaning trial
* Hemodynamic and Doppler-echocardiographic assessment whereas ECMO flow is gradually decreased to 66%, and to 33% of its baseline value and then to a minimum of 1–1.5 L/min

If steps 1, 2, 3 and 4 are validated and the patient has under minimal ECMO support LVEF of ≥ 20–25%, an aortic VTI of ≥ 12 cm and a TDSa ≥ 6 cm/s,
ECMO removal should be considered
Echocardiography in specific scenarios

Endocarditis

Habib et al., EHJ. 2015
Echocardiography in specific scenarios

Valvular disease

- Regurgitation
  - Acute vs chronic
- Stenosis
- Hemodynamic consequences
Echocardiography in specific scenarios

Prosthetic valve dysfunction

- Ring dehiscence
- Thrombosis
Imaging techniques in acute cardiovascular care

- Echocardiography in specific scenarios

  Prosthetic valve dysfunction
  - Ring dehiscence
Echocardiography in specific scenarios

Prosthetic valve dysfunction
  • Thrombosis
Echocardiography in specific scenarios

Pericardial disease

- Pericardial effusion
  - Tamponade
- Constrictive pericarditis
Echocardiography in specific scenarios

Pericardial disease
- Pericardial effusion
  - Tamponade
Echocardiography in specific scenarios

Pericardial disease
- Pericardial effusion
  - Tamponade
Echocardiography in specific scenarios

Pericardial disease
- Constrictive pericarditis
Echocardiography in specific scenarios

Pulmonary embolism

Konstantinides et al., EHJ. 2015

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Echocardiography in specific scenarios

Pulmonary embolism
Echocardiography in specific scenarios

Aortic emergencies
- Aortic dissection
- Intramural haematoma
- Penetrating ulcer
- Symptomatic aneurysm

Erbel et al., EHJ. 2014
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- Echocardiography in specific scenarios

  Aortic emergencies
  - Aortic dissection
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- Echocardiography in specific scenarios

  Traumatic cardiac injury

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- **Computed tomography angiography**
  - Coronary
  - Pulmonary
  - Aorta
Imaging techniques in acute cardiovascular care

- Computed tomography angiography
  - Coronary

MDCT coronary angiography should be considered as an alternative to invasive angiography to exclude ACS when there is a low to intermediate likelihood of CAD and when cardiac troponin and/or ECG are inconclusive.

Roffi et al., EHJ. 2016

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- **Computed tomography angiography**
  - **Pulmonary**

<table>
<thead>
<tr>
<th>CT angiography</th>
<th>I</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal CT angiography safely excludes PE in patients with low or intermediate clinical probability or PE-unlikely.</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>Normal CT angiography may safely exclude PE in patients with high clinical probability or PE-likely.</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>CT angiography showing a segmental or more proximal thrombus confirms PE.</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>Further testing to confirm PE may be considered in case of isolated sub-segmental clots.</td>
<td></td>
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</tr>
</tbody>
</table>

Konstantinides et al., EHJ. 2015

(A) Massive emboli in the left and right pulmonary arteries (B) Severe dilation of the right ventricle

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Imaging techniques in acute cardiovascular care

- Computed tomography angiography

- **Aorta**

  In stable patients with a suspicion of AAS, the following imaging modalities are recommended (or should be considered) according to local availability and expertise:
  
  - CT
  - MRI
  - TOE

  In case of initially negative imaging with persistence of suspicion of AAS, repetitive imaging (CT or MRI) is recommended.

  Chest X-ray may be considered in cases of low clinical probability of AAS.

  In case of uncomplicated Type B AD treated medically, repeated imaging (CT or MRI) during the first days is recommended.

  Erbel et al., EHJ. 2014

Type A aortic dissection

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Imaging techniques in acute cardiovascular care

- Computed tomography angiography
  - “Triple rule out”
    - Exclude potentially life-threatening causes of acute chest pain
    - Faster algorithm
    - Low admission rates

  - Radiation exposure
  - Contrast
  - More RCT are needed...

Chae MK et al., J. Cardiovasc Comput Tomograf., 2016
Turaco M et al., ESC Textbook, 2015
Imaging techniques in acute cardiovascular care

- **Cardiac magnetic resonance**
  - Etiology
    - Acute coronary syndrome/MINOCA
    - Miocarditis
    - Pericarditis
    - Takotsubo syndrome
    - Aortic disease
    - ...
  - Left/right ventricular function
  - Ischaemia/viability
  - Prognosis
    - Hemodynamic instability
    - Metallic implants, devices, ...
    - Gadolinium contrast

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- **Cardiac magnetic resonance**

  ✓ Etiology

- **Subendocardial**
  - Subendocardial infarction
  - Transmural infarction
  - Amyloidosis
  - Syst sclerosis

- **Mid-wall**
  - HOCM
  - Right ventr overload
  - Idiopathic Dilated CM
  - Myocarditis

- **Epicardial**
  - Sarcoidosis
  - Myocarditis
  - Anderson-Fabry
  - Chagas

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- **Cardiac magnetic resonance**
  
  ✓ Left/right ventricular function
Imaging techniques in acute cardiovascular care

- **Cardiac magnetic resonance**

  ✓ **Viability**

  ![Diagram showing cardiac magnetic resonance for viability assessment](image)

  *Kim et al. N Eng J Med 2000*

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- Cardiac magnetic resonance
  - Viability


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Imaging techniques in acute cardiovascular care

- **TAKE HOME MESSAGES**
  
  - Imaging techniques are indispensable for clinical decision-making
  
  - **Chest X-ray** is an easy-to-use and may reveal unsuspected clinical conditions
  
  - **FoCUS** and **lung ultrasound** are extension of the clinical examination
  
  - "**Triple rule-out**" approach may improve the triage of patients presenting with acute chest pain
  
  - Current applications of **cardiac magnetic resonance** offer a wide spectrum of indications in the setting of acute cardiac care