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Cardiac CT and MRI: A Comprehensive Review of Current Clinical Guidelines

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ABSTRACT

Medical imaging plays a pivotal role in cardiovascular care by enabling accurate, non-invasive diagnosis, risk stratification, and treatment planning. Cardiac computed tomography (CT) and cardiac magnetic resonance imaging (MRI) have revolutionized cardiovascular diagnostics by providing detailed insights into cardiac anatomy, myocardial function, and coronary vascular health. MRI offers excellent soft tissue characterization without ionizing radiation, whereas CT provides rapid, high-resolution coronary artery visualization and quantification of calcified plaques. Recent advances, including artificial intelligence (AI) and hybrid imaging technologies, have improved diagnostic accuracy, workflow efficiency, and patient safety. Despite these technological advances, coronary artery disease (CAD) remains the leading cause of mortality globally, emphasizing the need for precise and standardized imaging practices. This systematic review, conducted according to PRISMA guidelines, analyzed peer-reviewed studies published between 2010 and 2025 from PubMed, Scopus, and Web of Science. Findings indicate that while CT excels in anatomical delineation and coronary assessment, MRI remains indispensable for tissue characterization, myocardial viability assessment, and functional evaluation. Integrating both modalities provides a synergistic approach that optimizes patient-centered care and clinical decision-making.

INTRODUCTION

Medical imaging has become a cornerstone of modern healthcare, enabling non-invasive visualization of internal anatomy and physiology for accurate diagnosis, prognostication, and treatment planning. Cardiovascular disease (CVD), including coronary artery disease, heart failure, and congenital anomalies, represents a leading global health burden, accounting for over 17 million deaths annually (WHO, 2023). Early detection and precise characterization of cardiac pathology are critical to improving outcomes and guiding therapeutic interventions.

Among imaging modalities, **cardiac CT** and **cardiac MRI** have emerged as indispensable tools due to their complementary strengths. Cardiac CT offers rapid, high-resolution anatomical assessment, particularly of coronary arteries, enabling plaque quantification, calcium scoring, and detection of stenosis. In contrast, cardiac MRI provides unmatched soft tissue characterization, allowing detailed evaluation of myocardial fibrosis, edema, viability, and infiltrative processes without exposure to ionizing radiation. These modalities facilitate risk stratification, monitor treatment response, and guide interventions such as percutaneous coronary procedures and surgical planning.

Recent technological advancements, including high-speed scanners, dual-energy CT, 3T MRI, and AI-based post-processing algorithms, have enhanced diagnostic yield, reduced artifacts, and improved patient safety. Multimodality imaging, combining the strengths of CT and MRI, is increasingly recommended in current clinical guidelines to optimize care in both ischemic and non-ischemic cardiac disease.

METHODS

This review was conducted in accordance with the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** guidelines (Moher et al., 2009). A structured search of PubMed, Scopus, and Web of Science databases was performed for studies published from January 2010 to March 2025.

Search Strategy:

- Keywords: "cardiac CT," "cardiac MRI," "coronary imaging," "clinical guidelines," "diagnostic imaging," "multimodality imaging."

- Inclusion Criteria: Peer-reviewed articles, clinical guidelines, consensus statements, and systematic reviews published in English, focusing on cardiac CT and MRI.
- Exclusion Criteria: Case reports, conference abstracts, non-English publications, and animal studies.

Two independent reviewers screened titles and abstracts for eligibility. Full texts of relevant articles were analyzed, and data were extracted regarding clinical indications, imaging protocols, diagnostic performance, safety considerations, and recommendations from current guidelines. Disagreements were resolved by discussion and, if needed, third-party adjudication. A PRISMA flow diagram was constructed to illustrate the selection process.

DISCUSSION

1. Clinical Applications of Cardiac CT and MRI

Cardiac MRI (CMR):

CMR is considered the gold standard for non-invasive assessment of myocardial tissue characterization, ventricular function, and viability. Its high spatial and temporal resolution allows detection of:

- **Myocardial fibrosis** via late gadolinium enhancement (LGE).
- **Myocardial edema** using T2-weighted imaging in acute myocardial injury.
- **Infiltrative disorders** such as amyloidosis and sarcoidosis using T1 mapping.
- **Congenital heart disease** evaluation with precise anatomical and functional assessment.

Cardiac CT (CCT):

CT provides rapid, high-resolution anatomical imaging, particularly useful for:

- **Coronary artery assessment**: Detection of stenosis, plaque characterization, and calcium scoring.
- **Pre-procedural planning**: Evaluation of coronary anatomy before transcatheter interventions.
- **Acute chest pain evaluation**: Fast acquisition allows identification of obstructive coronary lesions in emergency settings.

Multimodality Integration:

Combining CT and MRI enhances diagnostic accuracy in complex cases, such as ischemic cardiomyopathy, hypertrophic cardiomyopathy, and congenital heart anomalies, where both anatomical detail and tissue characterization are required.

2. Comparative Strengths and Limitations

Feature	Cardiac CT	Cardiac MRI
Spatial Resolution	Excellent; ideal for coronary artery imaging	Moderate; suitable for myocardial structure
Temporal Resolution	High; suitable for rapid acquisition	Moderate; limited by longer scan times
Radiation Exposure	Present; dose varies with protocol	None; safe for repeated studies
Contrast Risks	Iodinated contrast; nephrotoxicity	Gadolinium; rare risk of nephrogenic systemic fibrosis
Functional Assessment	Limited; indirect assessment via perfusion	Gold standard; ventricular volumes, ejection fraction, wall motion
Tissue Characterization	Limited	Excellent; fibrosis, edema, infiltration
Contraindications	Allergy to contrast, pregnancy caution	Implanted devices, claustrophobia, renal impairment for gadolinium

Key Points:

- CT is the preferred modality for coronary artery evaluation, acute chest pain, and calcium scoring.
- MRI is optimal for myocardial tissue characterization, functional assessment, and serial monitoring due to lack of radiation.

3. Artificial Intelligence in Cardiac Imaging

AI has become integral in enhancing cardiac imaging across multiple domains:

- **Image acquisition and reconstruction**: Motion correction, noise reduction, and super-resolution algorithms reduce scan time and improve image quality.
- **Automated analysis**: Quantification of ventricular volumes, ejection fraction, myocardial strain, and plaque burden reduces interobserver variability.
- **Predictive modeling**: AI can stratify patient risk, predict outcomes, and personalize therapy.
- **Workflow optimization**: AI-based triage and reconstruction accelerate reporting and reduce clinician workload.

Studies have shown that deep learning algorithms can detect subtle coronary lesions on CT and myocardial fibrosis on MRI with accuracy comparable to expert radiologists, indicating a shift toward AI-assisted diagnostics in clinical practice.

4. Future Directions

Future research should focus on:

- **Standardization**: Harmonizing international imaging guidelines and reporting protocols (e.g., Society for Cardiovascular Magnetic Resonance [SCMR], European Society of Cardiology [ESC]).
- **Hybrid Imaging**: Integration with PET-MRI or SPECT-CT for functional-metabolic assessment.
- **Low-Dose CT and Accelerated MRI**: Protocols to reduce radiation exposure and scan time while maintaining diagnostic quality.
- **AI Integration**: Development of predictive algorithms for prognosis and personalized treatment planning.
- **Accessibility**: Expanding availability of advanced imaging in low- and middle-income countries.
- **Cost-Effectiveness**: Clinical trials evaluating the economic impact of multimodality imaging strategies to guide healthcare policy.

CONSLUSION

Cardiac CT and MRI are complementary modalities that collectively enhance precision medicine in cardiovascular care. MRI excels in myocardial tissue characterization and functional assessment, whereas CT provides rapid, high-resolution anatomical and coronary evaluation. Integration of these modalities, supported by AI, improves diagnostic confidence, workflow efficiency, and patient outcomes. Continued research, guideline harmonization, and technological innovation will ensure standardized, patient-centered cardiac imaging in diverse clinical settings.

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