# Mapping the landscape of multimodal and multi-omics AI/ML in cardiovascular disease: a visual framework for innovation

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**Background:** Multimodal and multi-omics data can revolutionize cardiovascular care by enabling artificial intelligence / machine learning (AI/ML) models to provide holistic, personalized insights. These models can enhance diagnostic precision by integrating imaging, clinical, and molecular data. Visual analytics can further aid interpretation, adoption, and trust in AI-driven tools.

**Purpose:** We aimed to visually map the current landscape of multimodal AI/ML approaches in cardiovascular disease (CVD) and to identify translational gaps, focusing on: (a) algorithm development, (b) data readiness and interoperability, (c) validation and deployment, and (d) ethical and implementation considerations.

**Methods:** A systematic review of peer-reviewed studies (last 10 years) was conducted using the Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA). Articles were screened and extracted for data modality, model type, clinical application, and validation methods. We used qualitative synthesis along with visual frameworks to highlight trends and underexplored areas. Risk of bias was assessed using PROBAST.

**Results:** While integrated multimodal systems remain limited, we developed visual tools including: a matrix of modality pairings versus clinical applications, a timeline of validation stages (development to clinical deployment), and a gap map identifying underused modalities. For example, one validation stage study combining electrocardiogram (ECG) and echocardiography outperformed human experts in diagnosing left ventricular hypertrophy. Another used echocardiography and cardiac magnetic resonance imaging to guide cardiac resynchronization therapy. A third linked transcriptomics and single nucleotide polymorphisms (SNPs) to predictive CVD risk models, identifying transcriptomic features and SNPs with strong predictive performance. Our visual mappings revealed clustering around imaging-genomic pairings but sparse integration of behavioral or wearable data. Most models remained untested in real-world clinical settings.

**Conclusions:** Multimodal AI/ML offers transformative potential for CVD care, but widespread clinical adoption will require real-world validation, integration, and interoperability. Our visual framework not only highlights technical opportunities but also uncovers policy and implementation gaps. Mapping modality usage, validation maturity, and integration readiness can guide researchers, developers, and regulators toward scalable, trustworthy AI-enabled clinical decision support tools.