Decoding the Digital Heart: Practical AI for Precision Diagnostics

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THE LANDSCAPE of modern cardiology is undergoing a profound transformation, driven by the emergence of AI as a powerful tool to enhance diagnostic precision and patient management. In a session titled 'Practical Artificial Intelligence Solutions for Precision Diagnostics in the Clinic' at the 2025 European Society of Cardiology (ESC) Congress, held in Madrid, Spain, leading experts converged to demonstrate how AI is moving from a futuristic concept to a pragmatic, indispensable part of everyday clinical care.

MINING BIG DATA FOR NEW BIOMARKERS

AI is reshaping cardiovascular medicine by enhancing the way clinicians interpret medical images, diagnose disease, and guide treatment decisions. According to Alexios Antonopoulos, 1st Cardiology Department, National Kapodistrian University of Athens, Greece, AI-driven imaging tools are addressing major unmet needs in cardiovascular care, particularly in early disease detection, personalised risk prediction, and workflow efficiency.

AI has already transformed routine imaging tasks, automating measurements such as ventricular volumes on cardiac magnetic resonance, saving clinicians valuable time and improving diagnostic consistency. More advanced applications, including automated plaque segmentation and quantification of coronary or epicardial fat, are redefining how clinicians perceive and classify disease.[1] For instance, AI tools can detect subtle imaging features of conditions like cardiac amyloidosis, often before symptoms appear, helping clinicians identify high-risk patients who would otherwise go undiagnosed.[2]

Antonopoulos explained that, by integrating imaging biomarkers with large-scale datasets such as the UK Biobank,[3] AI enables large cohort analyses and the discovery of new predictors of cardiovascular risk, such as vascular inflammation or perivascular fat attenuation. These insights support a shift toward individualised risk stratification and more precise management strategies.

To fully integrate AI into clinical practice, Antonopoulos emphasised the need for rigorous validation, regulatory oversight, biological grounding, and evidence from RCTs. When proven effective and cost-efficient, AI-assisted imaging can deliver on its promise to not only enhance diagnosis and prediction, but also to transform patient care through truly personalised cardiovascular medicine.

USING AI TO READ BEHIND THE ECG TRACES

Following on, Rohan Khera, Yale University, New Haven, Connecticut, USA, explored how AI can extract hidden clinical information from ECGs, transforming one of the world's most accessible diagnostic tests into a powerful tool for early disease detection and risk prediction. Every year, more than 300 million ECGs are performed globally, far exceeding all cardiac imaging tests combined, making it an ideal foundation for scalable AI innovation.[4]

Traditionally, clinicians interpret ECGs visually, identifying rhythm or conduction abnormalities, Khera explained. However, much richer information lies within the underlying voltage data that AI can process through deep learning techniques such as convolutional neural networks.[4] Khera's team at the Yale Cardiovascular Data Science (CarDS) Lab, New Haven, developed models that can detect structural heart diseases (such as left ventricular dysfunction, hypertrophic cardiomyopathy, aortic stenosis, and cardiac amyloidosis) using only ECG images, rather than specialised raw data. Remarkably, these models achieved >90% accuracy in distinguishing patients with reduced ejection fraction and validated consistently across global populations.[5]

The group also created smartphone-based tools that allow clinicians, or even patients, to capture ECG images with a phone camera or wearable device and instantly receive AI-driven insights without requiring internet connectivity. This opens the door to community-level screening for heart disease using affordable, portable devices.

Khera continued that, beyond diagnosis, AI-enhanced ECGs can also predict future risk of heart failure, outperforming standard clinical risk models and offering prognostic value even in asymptomatic individuals. As he emphasised, AI can "see what the human eye cannot," revealing disease signatures hidden in plain sight and democratising cardiovascular diagnostics worldwide.

BRIDGING MOLECULAR DATA AND DIGITAL DIAGNOSTICS

Tanja Zeller, The University Medical Center Schleswig-Holstein, Lübeck, Germany, explored how digital and molecular technologies can help decode the complexity of cardiovascular disease by integrating diverse layers of biological data. She likened biomarkers to puzzle pieces: each provides useful but incomplete information. To see the whole picture of disease, clinicians must combine molecular, clinical, and digital data in multidimensional analyses.

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Her first example focused on improving the diagnosis of acute myocardial infarction. Traditional triage relies on fixed troponin cut-offs and standard algorithms, which often leave many patients in an indeterminate zone.[6] Using machine learning models such as those developed in the Acute Coronary Syndrome (ACS) Pathfinder and Collaboration for the Diagnosis and Evaluation of Acute Coronary Syndrome (CoDE-ACS) consortia, Zeller's team incorporated multiple routine clinical parameters to calculate an individual's probability of acute myocardial infarction.[7,8] These digital tools, validated in >20,000 patients, allowed three times more people to be immediately and safely ruled out compared with current practice.[7,8]

Moving beyond diagnosis, she described how integrating multi-omics data, including genomics, transcriptomics, proteomics, and immune profiling, can uncover the molecular pathways driving acute and chronic coronary syndromes. Studies using such approaches have identified immune cell shifts and cytokine signalling patterns that may predict outcomes after infarction.[9]

Her second example addressed atrial fibrillation, where combining genetic, RNA, and protein data with AI tools identified molecular variants linked to disease development and improved risk prediction.[10] In a striking proof of concept, her team trained deep learning models to predict blood N-terminal pro-B-type natriuretic peptide (NT-proBNP) levels directly from ECG recordings, demonstrating how digital tools might replicate expensive laboratory tests.[11]

Zeller concluded that merging omics-based biomarkers with digital diagnostics could transform cardiovascular care, but success will depend on data quality, cross-disciplinary collaboration, and careful clinical validation.

DIGITAL BIOMARKERS IN ACTION

The final speaker, Florian A. Wenzl, Center for Molecular Cardiology, University of Zurich, Switzerland, explored the current role and future potential of AI in clinical decision-making. He began by emphasising that AI is no longer a future concept but an established reality that already influences many aspects of daily life and medicine. The rapid progress in computing power and data availability has led to exponential growth in AI capabilities, enabling systems to achieve superhuman performance in selected tasks, including diagnostics and prognostics.

Wenzl outlined how AI models in cardiovascular medicine are increasingly applied across four key domains: disease phenotyping, diagnostics, prognostics, and treatment decisions.[12] He stressed that a range of data sources, such as clinical findings, imaging, and laboratory values, can be used to train predictive models, though selecting the most relevant data for each clinical question remains crucial.[12] Rigorous evaluation, including external validation and comparison with current standards of care, was highlighted as essential for ensuring reliability and trust.

A central theme of his talk was that AI model assessment should follow the same methodological principles as conventional statistical models, using metrics like sensitivity, specificity, and calibration. Wenzl also addressed concerns about explainability, suggesting that practical utility can sometimes outweigh full mechanistic understanding, as is often the case with effective drugs.

He concluded with examples of AI applications, from predicting coronary artery disease by facial photographs[13] to detecting atrial fibrillation by speech analysis,[14] and emphasised that transparent reporting, external validation, and integration into clinical guidelines will be vital for safely realising AI's promise in personalised medicine.

CONCLUSION

AI is transforming cardiology, enhancing early diagnosis, personalised risk prediction, and patient management. From imaging and ECG analysis to multi-omics integration, this session demonstrated how AI uncovers hidden disease signatures, automates workflows, and informs clinical decisions. Rigorous validation and interdisciplinary collaboration remain essential to safely translate these innovations into improved cardiovascular care.

References

1. Lin A et al. Deep learning-enabled coronary CT angiography for plaque and stenosis quantification and cardiac risk prediction: an international multicentre study. Lancet Digit Health. 2022;4(4):e256-65.
2. Antonopoulos AS et al. Computed tomography-derived myocardial radiomics for detection of transthyretin amyloidosis in patients with severe aortic stenosis. Amyloid. 2025;32(3):226-37.
3. UK Biobank. 2025. Available at: https://www.ukbiobank.ac.uk/. Last accessed: 14 October 2025.
4. Mason F et al. AI-enhanced reconstruction of the 12-lead electrocardiogram via 3-leads with accurate clinical assessment. NPJ Digit Med. 2024;7(1):201.
5. Sangha V et al. Detection of left ventricular systolic dysfunction from electrocardiographic images. Circulation. 2023;148(9):765-77.
6. Byrne RA et al. 2023 ESC Guidelines for the management of acute coronary syndromes. Eur Heart J. 2023.44(38):3720-826.
7. Neumann JT et al. Personalized diagnosis in suspected myocardial infarction. Clin Res Cardiol. 2023;112(9):1288-301.
8. Doudesis D et al.; CoDE-ACS Investigators. Machine learning for diagnosis of myocardial infarction using cardiac troponin concentrations. Nat Med. 2023;29(5):1201-10.
9. Pekayvaz K et al. Multiomic analyses uncover immunological signatures in acute and chronic coronary syndromes. Nat Med. 2024;30(6):1696-710.
10. Assum I et al. Tissue-specific multi-omics analysis of atrial fibrillation. Nat Commun. 2022;13(1):441.
11. Neyazi M et al. Deep learning-based NT-proBNP prediction from the ECG for risk assessment in the community. Clin Chem Lab Med. 2023;62(4):740-52.
12. Lüscher TF et al. Artificial intelligence in cardiovascular medicine: clinical applications. Eur Heart J. 2024;45(40):4291-304.
13. Lin S et al. Feasibility of using deep learning to detect coronary artery disease based on facial photo. Eur Heart J. 2020;41(46):4400-11.
14. Golovchiner G et al. Automated detection of atrial fibrillation based on vocal features analysis. J Cardiovasc Electrophysiol. 2022;33(8):1647-54.