Artificial Intelligence and Digital Biomarkers: A Revolution in Cardiovascular Diagnostics

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THIS YEAR, the European Society of Cardiology (ESC) Congress 2024, which took place in London, UK, between 30th August–2nd September, hosted an insightful symposium entitled 'Artificial intelligence unleashed on digital biomarkers: a new era in personalised cardiovascular healthcare'. The session explored the applications of AI in cardiac diagnostics, highlighting its potential to positively impact patient care. The speakers covered key topics, including how vascular retinal imaging could predict cardiovascular risk and whether speech analysis could aid in the detection of acute decompensated heart failure.

RETINAL IMAGING FOR CARDIOVASCULAR RISK ASSESSMENT

Sungha Park, Yonsei University, Seoul, Republic of Korea, presented a compelling case for the use of retinal imaging in cardiovascular risk assessment. He highlighted the strong correlation between the media-to-lumen ratio of small arteries and retinal arterioles, noting that retinal arterial narrowing may reflect broader arterial diseases, including those in the kidneys and brain.[1] Retinal arterial remodelling, indicative of systemic changes in small arteries, is associated with adverse cardiovascular complications.[2] Typical signs of arterial damage in the retina, such as microhaemorrhages and microaneurysms, are also linked to cardiovascular disease.[3]

Despite the clinical significance of these findings, there is often a lack of consensus among ophthalmologists regarding the diagnosis of retinal abnormalities, as interpretation can be subjective. AI technology has already demonstrated high accuracy in diagnosing ocular diseases like diabetic retinopathy and glaucoma, as well as measuring vascular dimensions. A 2018 study showed that AI could predict cardiovascular risk factors, such as age, gender, and smoking, from retinal fundus photographs with remarkable accuracy.[4]

Park's team explored whether deep learning-based analysis of retinal images could predict coronary artery calcium (CAC), a known cardiovascular risk marker.[5] Using a large dataset of 28,000 retinal images from multiple health centres and the UK Biobank, they trained a deep learning model that successfully predicted the presence of CAC.

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The model showed a correlation between higher scores and risk factors, such as age, male sex, hypertension, and diabetes. This deep learning model, named Reti-CVD, showed promise in stratifying cardiovascular risk and performed comparably to traditional risk models like Pooled Cohort Equations (PCE) and QRISK®3 (ClinRisk, UK).

Further studies[6] validated the association between retinal arterial changes and cardiovascular disease, leading to the approval of the deep learning fundoscopic model by the Ministry of Food and Drug Safety of the Republic of Korea in 2023 for clinical use. The system offers advantages, such as minimal space requirements, low radiation exposure, and quick results within 5 minutes, making it suitable for use in the clinic. Although more validation is needed, early results suggest that this AI-based approach could be a valuable, cost-effective alternative to traditional cardiovascular risk assessments, especially in cases where access to more expensive and time-consuming diagnostic tools like CT scans is limited.

Given small vessel remodelling in the retina is a marker of both systemic organ damage and adverse cardiovascular outcomes, using deep learning systems to visualise the retina's microvasculature can provide more precise cardiovascular risk stratification, particularly for individuals in borderline to intermediate risk categories.

CAN SPEECH ANALYSIS DETECT HEART FAILURE?

Abhinav Sharma, McGill University Health Centre, Montréal, Canada, introduced the evolving use of voice analysis to detect acute decompensated heart failure.

He highlighted the increasing integration of mobile applications in healthcare due to lower costs and higher mobile phone penetration. In heart failure, while symptoms like dyspnoea and fatigue are well-known, the impact of speech changes due to fluid overload is less explored. Sharma and his team initially studied voice detection using chatbots during the COVID-19 pandemic and found high accuracy in symptom detection. However, they have now moved to more advanced AI-based speech analysis.[7]

Speech analysis in patients with heart failure focuses on how pulmonary oedema affects vocal folds, altering speech characteristics like jitter and shimmer, which are detectable through both time and frequency domain analysis. Early studies showed that volume changes from fluid retention affected speech, with one trial noting that phonation threshold pressure rose in response to diuretics.[8] Other studies used acoustic analysis of patients' speech to detect creakiness, a feature that correlated with changes in body weight.[9]

Recent research that focused on developing vocal biomarkers from large datasets, analysing various speech features to predict heart failure risk, and, although the results showed some promise, the accuracy was moderate.[10] Further studies, including a trial in 2022 that analysed speech in multiple languages,

reinforced the concept that volume status affects the voice, demonstrating detectable changes between “wet, congested, and dry,” decongested states.[11]

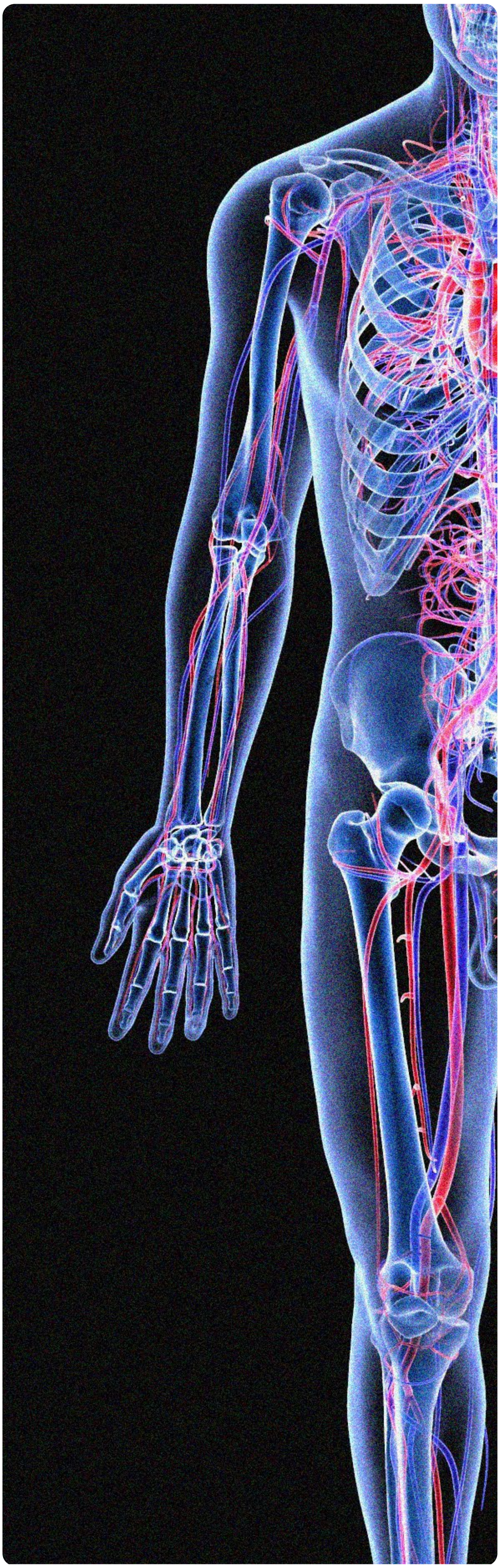
Sharma emphasised the shift from invasive monitoring like CardioMEMS to non-invasive, cost-effective methods like mobile apps that can frequently monitor patients with heart failure. Despite the promise of such technology, challenges remain, such as privacy concerns, potential false positives due to ambient noise, and increased administrative burden. Ultimately, the success of voice-based monitoring will depend on whether it can significantly impact patient management and outcomes.

Future directions could include simplifying voice biomarkers and addressing privacy and cybersecurity concerns, while the long-term goal is to ensure that these technologies improve heart failure management by offering meaningful insights and care alterations.

DIGITAL BIOMARKERS FOR PATIENT STRATIFICATION

Florian Wenzl, University of Zurich, Switzerland, emphasised that, although AI is still evolving, it is becoming a crucial tool in predicting outcomes and aiding decision-making in clinical settings. AI’s role in risk stratification spans various areas, such as analysing clinical data, biomarkers, imaging, and wearable device data, to predict patient outcomes and improve treatment strategies.[12]

Wenzl discussed current applications, focusing on patients with non-ST segment elevation acute coronary syndrome (NSTE-ACS) and post-percutaneous coronary intervention. The development of the GRACE 3.0 score, a new AI-driven tool for risk stratification in patients with NSTE-ACS, was also highlighted, given that this score, which has been validated using large datasets, outperformed previous versions by accounting for sex-specific differences in risk factors.[13] The GRACE 3.0 score has shown an improved ability to predict risk, particularly in low-to-intermediate risk patients who may benefit from early invasive treatment and is now available as an online calculator to assist clinicians.[14]



In a broader context, Wenzl pointed to future AI applications in medicine, particularly in integrating diverse data sources ranging from biometric data to wearable technology. In his concluding remarks, he underscored the immense potential of AI in medicine, while also noting the importance of rigorous external validation to ensure reliability and accuracy in clinical practice.

MANAGING ARRHYTHMIA WITH ARTIFICIAL INTELLIGENCE

Renate B. Schnabel, University Heart and Vascular Centre in Hamburg, Germany, provided an update on AI-based strategies for diagnosing and treating arrhythmias. Although advancements are continuously being made, AI and machine learning are already enhancing arrhythmia management, particularly in electrocardiogram (ECG) analysis, where deep learning algorithms help detect patterns and signatures in heart rhythms. AI is also being applied in virtual heart simulations, cardiac imaging, and robotics, while advances in telecommunication support AI-powered atrial fibrillation (AF) screening, Schnabel explained.

Schnabel highlighted the potential of combining big data from electronic health records and other sources to build predictive models for AF. She discussed the use of AI to identify individuals at high risk of AF, investigated in a recent study, although low patient engagement in this limited its effectiveness.[15] However, among those who participated, AI screening nearly doubled AF detection rates. AI applications in smartphone-based pulse detection, or photoplethysmography, have shown strong correlations with ECG data, improving arrhythmia management, particularly in post-ablation monitoring of patients with AF.

AI's role in analysing biomarkers to predict AF and its adverse outcomes has been explored by her team, who used machine learning to analyse biomarkers and clinical risk factors in a large cohort study.[16] The results showed that AI-based predictions, including those involving the heart failure marker, NT-proBNP, were comparable to traditional statistical methods, confirming the validity of these AI models. Further research has demonstrated that AI could predict AF and other cardiovascular conditions using ECG data, even outperforming some conventional methods in identifying high-risk individuals for AF during monitoring.[17]

Schnabel stressed the importance of understanding how AI algorithms make decisions, advocating for methods like attention maps and deep learning models that can help clinicians interpret AI predictions. She noted that the future of arrhythmia care will likely involve combining data from multiple sources, such as ECG, MRI, and simulations with AI to improve diagnostics, treatment, and risk prediction. However, she also highlighted the necessity for trustworthiness, reliability, and clinical validation to ensure AI's safe and effective implementation in cardiology.

CONCLUSION

As the symposium closed, a discussion raised a crucial issue regarding the interoperability of data and technologies in the medical field, particularly for improving risk prediction in AI-driven medicine. Given the industry is still in its early stages, only a tiny fraction of the vast amount of data collected daily from hospitals, wearables, and even public sources is being utilised in AI projects. The experts emphasised that it remains unclear which types of data will ultimately lead to the most accurate predictions, underscoring the need to integrate more diverse sources of information and the session concluded with optimism about the future of AI in cardiovascular medicine, emphasising the importance of ongoing collaboration and discussion on these emerging technologies.

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