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Authors

Quer, Giorgio
Muse, Evan D
Topol, Eric J
et al.

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Long Data from the Electrocardiogram

Giorgio Quer, Evan D. Muse, Eric J. Topol, Steven R. Steinhubl
Scripps Research Translational Institute, La Jolla, California, USA

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Address for Correspondence:
Giorgio Quer, PhD
Scripps Research Translational Institute
3344 North Torrey Pines Court, Plaza
La Jolla, CA 92037
Office: 858-784-2094
gquer@scripps.edu

The first capture of the electrical activity of the heart – the PQRST complex – was in 1895 by Willem Einthoven, using a 600-pound machine and 5 skilled operators, with a simple request for patients to place their hands and one foot inside buckets filled with an electrolyte solution. The 12-lead ECG in hospital and clinic settings evolved, requiring a big machine on wheels, multiple cables for each limb and across the chest. Now through our fingertips touching a sensor on the left leg, forming Einthoven's triangle, we can instantly record a high quality 6-lead ECG to a smartphone. This technology will make it possible to easily monitor extensive heart electrical activity virtually anywhere, at any time and as frequently as desired. With this new capability comes daunting challenges in the accurate interpretation of data.

Algorithms interpreting ECGs dates back to 1970, when the first rule-based algorithms – using hard coded human interpretable features – were designed. These static rules have been improved over time but still result in inaccuracies. That is now changing thanks to advances in artificial intelligence (AI). Using neural networks able to autonomously learn from large datasets of human-labelled ECGs, algorithms have been developed – and tested in retrospective studies - that can diagnose heart rhythm disturbances and myocardial infarctions, as accurately as cardiologists. But this could be just the beginning. Deep neural networks can be used to train machines to identify patterns humans can't. The combination of AI and a growing corpus of longitudinal data, made available through personal ECGs via watches and smartphone attachments, might move the field towards the ambitious goal of predicting future events based on a single ECG tracing. Research using machine learning has shown that findings within the ECG can estimate serum electrolyte levels, predict left ventricular function, likelihood of atrial fibrillation and even identify the probability of 1-year mortality from what have been read out as normal ECGs, although all still require prospective, real-world validation.

Routinely, ECG monitoring is limited to a 12-lead ECG at an annual checkup or in preparation for surgery. That mere 10 seconds of ECG monitoring is unlikely to capture sub-clinical but still meaningful real-world cardiac events or subtle changes over time. Instead, a longitudinal view of cardiac electrical activity is needed---"long data". However, the potential volume of patient-collected ECG data would overwhelm over-extended systems of care. The combination of smartphone ECG monitoring plus AI-based analytics involving large data-streams linked with clinical data, would allow for the evaluation of an individual's ECG over time and the detection of subtle changes, including silent ischemia, and even those not recognizable by human readers. Existing AI techniques, based on recurrent neural networks, particularly long short-term memory networks, will provide a starting point towards the development of personalized AI able to identify temporal changes in the ECG. Potentially, this individualized approach could allow for real-time automatic identification of actionable findings.

But for the diagnostic capabilities of ECG to be fully realized a great deal of work and learning is still required. Minimizing unnecessary alarms – or achieving a false positive rate of close to zero - will be one of the greatest challenges of any wearable AI health-related technology made for the broad consumer market. In addition, many unknowns exist when it comes to the return of understandable and actionable information to the individual. A bespoke approach, based on the individual's preferences, could be provided by a caregiver if desired. However, to be affordable and broadly scalable, AI could be used to learn individual preferences and to continuously implement, test and refine personalized feedback, from behavioral suggestions to cardiac alerts. Finally, rigorous evaluation in large prospective clinical trials is needed to establish the costs (healthy individuals falsely alerted) and benefits (early alerting leading to improved outcomes).

Despite these challenges, individual ECG monitoring has the potential to allow cardiac screening at an unprecedented scale in millions of individuals and reduce geographical and economic burdens to health care. These technologies could become an irreplaceable asset to physicians, allowing a cost-effective longitudinal view into the cardiovascular system, and to individuals, providing a personalized approach that can detect changes in the individual ECG at any point of the lifespan.

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Further reading

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