AI-Augmented ECG Interpretation Using Smartphone Technology

Announcer: Welcome to Mayo Clinic's ECG Segment: Making Waves, Continuing Medical Education podcast. Join us every other week for a lively discussion on the latest and greatest in the field of Electrocardiography. We'll discuss some of the exciting and innovative work happening at Mayo Clinic and beyond with the most brilliant minds in the space, and provide valuable insights that can be directly applied to your practice.

Dr. Kashou: Welcome to Mayo Clinic's ECG Segment: Making Waves. We're so glad you could join us. Today, we have an exciting episode planned for you as we discuss artificial intelligence augmented ECG interpretation using smartphone technology. We have an expert discussing joining us who will provide us with a unique perspective and his own experience on this topic, so let's get started. The ECG remains critical to clinical practice. With the advent of new artificial intelligence augmented ECG algorithms, we are witnessing exciting advances. These developments have the potential to improve patient care and clinical workflow. In this episode, we will discuss ECG interpretation using smartphone technology including AI-powered ECG, digitization, existing challenges in automated ECG interpretation, and the future of AI in electrocardiography. We're fortunate to have Dr. Robert Herman with us to discuss this work further. Dr. Herman is a physician-scientist with a robust technological background and a deep understanding of AI and machine learning. He completed his medical degree in Vienna, Austria. In 2021, he was accepted to the CardioPath program and started his PhD work, his thesis at the University of Naples, Italy. In 2022, he accepted the invitation to serve as a committee member of the European Society of Cardiology in Research, Digital, Work, and Innovation. His primary focus is applying AI to improve the diagnosis and management of acute coronary syndromes, heart failure, and arrhythmias. In 2019, he co-founded Powerful Medical, a certified medical device manufacturer designing, developing, and distributing software as a medical device for AI-powered diagnostics and treatment. As the Chief Medical Officer, he has led the research development and clinical evaluation of PMCardio, an AI-powered class 2B certified medical device aiding clinicians in diagnosing and managing over 40 cardiovascular diseases. Dr. Herman, what a true honor to have you with us, thank you so much for making time to join us.

Dr. Herman: Thank you, Anthony, thanks for the invitation. It's always a pleasure seeing your podcast pop up on my Spotify, and it's really exciting to hear the space that we're working in has a high representation and a lot of researchers involved in this.

Dr. Kashou: Yes, the... You know, it's when we see your work and I, you know, I've been following you for some time and we've grown to understand what we do, but I think it's... You know, I'm really excited to see what you're doing and learning more about your book, maybe you could share a little bit with the audience of, you know, why you developed this AI-powered ECG digitization and how it actually works so that they can be more familiar with it.

Dr. Herman: Great question. So we founded Powerful Medical in Europe and unfortunately, Europe didn't really manage to tackle digitization as well as the US. You know, Germany still uses facts as the primary method of transmitting medical data and unlike the Mayo Clinic, we didn't really have 40 years worth of digital ECGs to start our AI development, and for this reason, we really started working on a pipeline of algorithms that... Well, basically, extends our

access to more data to really train and validate our AI algorithms. So in short, our AI ECG digitization pipeline can convert and standardize any image of an ECG of any format or any manufacturer and really convert this to a fully digital ECG, maintaining the original sample frequency of the ECG. So really, as if it was coming out of the ECG machine. We can process really ECGs looking like this and note to the listeners, I'm holding up quite a messy ECG. We can really process and standardize any paper crumples on the ECG, we can resolve overlapping waveforms that often happen, and we can remove coffee stains or scribbles and are not therefore, limited to high quality ECG scans as input. So in short, we convert any image of any ECG of any device to a fully-digital ECG that we can use for further processing.

Dr. Kashou: It's really neat, especially as you mentioned, some of the limitations may be more resourced impoverished areas or don't have the digital mechanisms to do that and, you know, it's nice to know that, you know, any coffee stain that I put on the paper can be improved and even probably the glare, and I've seen a lot of it, it's quite remarkable, so it's amazing. I wonder, what do you see as the current challenges of automated ECG interpretation and, you know, how do we actually tackle them?

Dr. Herman: So, of course, we as a company, we're not only involved in the ECG digitization space, right? We digitize the ECGs to further process them and I would summarize the current challenges in this ECG interpretation space in four major points. First, I think there is lack of standardization and this is clear for a lot of domains in medical. ECG interpretation is still quite subjective and there is little consensus, for example, with the left bundle branch block criteria or the diagnosis of LVH from the ECG. If you doubt this, just look at a comment section on Twitter or Facebook where people post ECG cases quite frequently. Some of these conversations get really heated and there is a little consensus, especially on the odd looking ECGs that are not as picture book. Point number two is that the non-AI solutions that computerized the electrocardiogram are very susceptible to noise. We see that with the existing algorithms where if the naturally occurring noise that usually occurs in the clinic, like high frequency noise when the waveform is really fuzzy or when the baseline of the waveform wanders, these non-AI solutions are very susceptible to that and these small noise artifacts can really trick the interpretation algorithm. Point number three, I'd say is the fact that ECG interpretation is I would say not only dependent on the ECG waveform itself, but also can be very affected by the clinical parameters such as age, gender, or the symptoms of the patient. These parameters really have a huge influence on the resulting diagnosis, but not only the diagnosis, but also the triage and management of the patient. So for example, a classic case is an incidental finding of a right bundle branch block or then, you know, the right bundle branch block in a context of acute right heart strain during pulmonary embolism, right? Those are two different things that have different levels of importance, however, you can only figure that out once you add the clinical parameters of the patient to the picture, and I'd say number four is really that the fact that even though there is a lot of publicly available ECG data out there, these data sets are frequently inaccurate and not large enough to actually train and validate a model.

Dr. Kashou: It's so true, those are, you know, a lot of challenges and I know your team's working on, you know, how do we address some of those and I think that digitization that you guys have done, you know, helps that and even, you know, on the social media, it is remarkable to see that and LVH left bundle, I know a lot of people go back and forth on, you know, what is the true

criteria, you know. You know, maybe a lot of people with LVH have left bundle, but, you know, the criteria is debatable, especially when you look at the early studies. Now, maybe we could turn our attention, unless you have something you wanted to to add to that, but I'd like to maybe go to the medical device, PM Cardio, what do you think, can we move on to that?

Dr. Herman: PM Cardio is basically a fully-certified medical device in the form of a smartphone app and it's available on both iOS and android and it really gives access to any healthcare professional with an access to a 12-week ECG to really diagnose and interpret the ECG on the level of a cardiologist. So the way it works is they take a picture of an ECG and as I mentioned in the previous question, we are compatible... Due to our ECG digitization, we're really compatible with any 12-lead ECG device, be it paper form or, you know, photo of the monitor, and our technology converts this image into a fully-digital waveform and then we run our AI algorithms that detect up to 38 different cardiac abnormalities on the ECG. We do the basic rhythm analysis, we do the arrhythmias, we detect the infarctions, and the hard blocks, and I think the big feature of PM Cardio is that the medical device doesn't stop with the diagnosis. So we actually put this diagnosis into the clinical context of the patient, as I mentioned, tackling the fact that the clinical context has a lot of weight in diagnosing the patient essentially and deciding what the next step is, and we really... Basically, combine the diagnosis with a symptom checker that gathers the clinical context, the clinical parameters of the patient and outputs decision for referral and further diagnostic and treatment procedures. So PM Cardio really is a tool to diagnose any ECG and then recommend treatment and referral decision. So it's a tool for non-cardiologists healthcare professionals. Now, we have validated PM Cardio... Yeah?

Dr. Kashou: No, go ahead, I was wondering, what does the validation process kind of look like in all this?

Dr. Herman: Right, so the validation aspect, I think, it's really important when working with AI and we have validated PM Cardio on the largest data set of over 12,000 ECG test cases and we have also tried to benchmark PM Cardio, comparing it to the current state of the art. So for us, it's represented by general practitioners, the family physicians, and the cardiologists. We were able, in this validation, to really demonstrate a statistical superiority over the non-cardiologists healthcare professionals, so the family physicians, and we were able to also show that the medical devices actually non-inferior to cardiologists in all of the diagnoses across the board. We've improved arrhythmia detection by five times and also improved the detection of acute DMI when compared to the state of the art, and on the second aspect, because, of course, PM Cardio consists of the diagnosis, but also then the management. We actually, in 2022, ran one of the largest randomized control trials, trialing cardiac AI software with two health insurance companies in Europe and 58 participating primary care centers where we enrolled more than 800 patients. In short, what we've done is we've... Basically, the participating family physicians in 50% of the cases, they've seen the PM Cardio, an analysis of the ECG and the recommendation for referral, and in 50% of the cases, we were able to just collect the standard of care. So all of the randomization was really performed within the app and we're currently analyzing the results. What we know so far is that there is a high adherence rate towards what PM Cardio has recommended in the intervention arm and we're now analyzing the other endpoints such as the percentage of adequately referred patients in the intervention group compared to the control

group, and also, other health economic endpoints that quantify the costs of the inadequately referred patients.

Dr. Kashou: Yeah, that's really important. Look forward to that trial coming out. It's exciting that you're taking it to the next level and, you know, seeing how does it impact, you know, at the clinical level 'cause that's where, you know, you're wanting to take this software, which is really important. So what's, you know, next for AI-powered ECG in... You know, how can we unlock its full potential?

Dr. Herman: I think there is a lot of interesting research in this space and, you know, there is something that we're doing with the company and we are trying to always unlock more from the ECG. Of course, the ECG is currently our primary input that we process within the company and I think there are three ways I see AI-powered ECG really evolving along the next couple of years. I think we will move away from training on subjective interpretations to really training and evaluating our models on objective outcome parameters such as angiographic results or echocardiographic parameters. We see really an influx in this space and a lot of work also pioneered by the Mayo Clinic and we're also active here. So we have recently worked with Dr. Steven Smith and Dr. Pendell Meyers on an algorithm detecting even the more subtler acute coronary occlusion. We validated this algorithm on European and US cohorts and we were able to really increase, quite notably, the sensitivity of detecting acute coronary occlusion, while maintaining the specificity of the STEMI criteria. So really improving the diagnosis of the acute heart attack patients, we can really detect these patients hours earlier than the STEMI criteria and send them accordingly to the cath lab. So I have a study coming out very soon and we also focus on other areas such as heart failure EP and sudden cardiac death rolling out soon after this ACS module. I think the second point where I see this... Or second path where I see this going is really in the predictive capabilities phase. So we are working on really predicting the risk for these acute events occurring and really trying to analyze ECGs consecutively in time to really try and see who will actually develop this acute event and try and prevent that from happening, and I think with the advances in AI, I think what will definitely be quite interesting is the processing of the raw ECG data itself. You must know that due to the, I'd say limited human capabilities, we actually have filters on the ECG device, the devices themselves, so hardware filters that filter the waveform and we do that because, of course, the human eye cannot process such a messy waveform as found in this raw ECG data, but I think with the advances of AI, we can actually utilize AI to look at these raw signals and I think this could be the key to really unlocking more context from the ECG and enabling even more complex topics such as an in-depth analysis of the P waves or trying to predict precursors to atrial fibrillation.

Dr. Kashou: This is great, and it's really clear that the ECG remains an essential aspect of patient care, and while we continue to witness advances in electrocardiography, those that Robert and his team are doing, there's still challenges with automated ECG interpretation that exists. Nevertheless, we, I remain optimistic that a solution is inevitable. Dr. Herman, thank you so much for sharing your work and experience on this topic. I look forward to learning more about your exciting work and watching your future unfold. On behalf of our team, thank you for taking time out of your day to join us, it's really been a true pleasure.

Dr. Herman: Thank you very much.

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