Device Agnostic Artificial Intelligence-based Analysis of Ambulatory ECG Recordings

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. Today we have an exciting episode planned for you as we look at the evolution of ECG interpretation software over the years and what's to come. We have an expert discussant joining us. He's back with us again and we're excited to have him. Now, the ECG is vital in making timely medical decisions that can save lives. Computerized ECG interpretation software was developed to support clinical decision making and workflow. While it does take its fair share of criticism for its imperfections, it still plays an important role in clinical practice today and the field of electrocardiology appears to be going through a renaissance. What does the role of the computer interpretation look like today and where do artificial intelligence based models fit in with the future of the field? These are just some of the questions we'll address today with Professor Peter Macfarlane. Professor Macfarlane is emeritus professor and Hon. senior research fellow at the University of Glasgow. He was Professor in Medical Cardiology from 1991 to 1995 and Professor of Electrocardiology from 1995 to 2010. His basic training was in math and natural philosophy and he obtained a Doctorate of Science degree in 2000 for a compilation of publications on computer assisted reporting of electrocardiograms. The work of his team has been adopted commercially and the University of Glasgow ECG interpretation program developed in his laboratory is currently used worldwide. He has a particular interest in the differences in ECG appearances due to age, gender, and ethnicity and as a result of this, he has influenced international guidelines for the ECG definition of acute myocardial infarction or heart attack. Now, Professor Macfarlane has also established a central ECG laboratory for handling ECGs recorded in the national and international clinical trials, as well as epidemiological studies, including the landmark West of Scotland Coronary Prevention Study. He's published well over 400 scientific papers, 14 books and probably more at this point and has led so many conferences. He was also jointly awarded the 1998 Rijlant International Prize in Electrocardiology by the Belgian Royal Academy of Medicine and in January, 2014, he was awarded CBE for services to healthcare. Professor Macfarlane, thank you so much for joining us again. I'm really glad to have you back with us.

Dr. Macfarlane: Oh, thank you for the invitation. Very pleased to be here.

Dr. Kashou: Now, it's always fun to talk to you and I've noticed a lot of our audience love what you have to say. In our previous episode, you shared a lot about your background and how you got into the whole world of computerized electrocardiography. I found it really fascinating, and I'm sure many others did but those that missed that, maybe you could share a little bit of your background.

Dr. Macfarlane: Well, very briefly. You mentioned my basic degree in mathematics and natural philosophy. In my final year, the professor of mathematics said one day that the cardiologist at

one of the major hospitals in Glasgow were looking for someone to follow up what they had noticed was a trend towards the use of computers for ECG interpretation. I was lucky enough to obtain that post. I worked there as a PhD student and then became assistant lecturer during my PhD work. I remember my final examination, we had the Professor of Mathematics, Professor of Cardiology, a Professor of Computing Science and another Professor of Cardiology locally and externally. It's quite a wide ranging topic subjects that one had to learn and attend various conferences, et cetera, to become familiar with the field. We moved on from there, we developed a small system that was used within the Royal Infirmary. We believe it was the first automated ECG interpretation system in a hospital using a small laboratory computer; first worldwide. At that time, we had a small system. We were only capable of processing three leads, and that took one minute, but then we moved on from there, and the 12-lead ECG, we managed to get that running supported by the Scottish government. In 1981, software was taken up commercially by Siemens-Elima. They bought Burdick in North America and then gradually things expanded and we were allowed to sell the license... Sorry, license to software worldwide once Burdick gave up the sole rights to the software. That's very quickly a summary of how we got to where we are at the present. We still have inquiries very regularly for use of the software by new companies. I'm not sure where they all come from but I can assure you, they come out the woodwork as far as I'm concerned.

Dr. Kashou: It's really fascinating. It does make sense, you know, hearing a little bit of how you had all these different professionals in the room and how you got here. It's fascinating and it's some journey and those that want to hear more about that, I'd refer you back to our first episode. Now, I wanna move on to the ECG. Now, medical staff, we generally accept a variety of blood tests that we get, right? Every day in the hospital setting. When we look at the computer in terms of non cardiologists should they do the same with automated ECG interpretations? And from that, I wonder if you could then expand on, you know, where you see the role of the computer ECG interpretation software in clinical practice today. What does that look like for each discipline and level of expertise? Does that look different of how they should use this tool?

Dr. Macfarlane: Well, thank you. That's quite a few questions. Where do I begin? Yes, certainly, one might be inclined to say "These are blood tests, these are the results." But if there was a really drastic measurement that you felt was wrong, you would question it and maybe do a repeat test. You would always say to those looking at automated interpretations that a computer is not infallible. Don't assume that 100% of interpretations will be correct. We would say that the automated interpretation is a second opinion. Now, if someone looks at a fairly straightforward normal ECG and most physicians and surgeons should be able to recognize a straightforward normal ECG and the computer report says it's got some form of abnormality, then they would know themselves that there was a problem, that the machine had been wrong. I don't want to underplay the machine. We've known from many studies that the machine can be better than even a junior fellow in cardiology. We've seen that through the years. We would never see it to a consultant position cardiologist that the computer was better. That's impossible. You'll never see that and the reason for that is that one cardiologist would differ from another. You can't say to any cardiologist that the automated interpretation is better. We have to have an element of training that the computer interpretation is never to be regarded as 100% correct. Definitely regarded as a second opinion; that's the way I would tend to look at it. Why would we bother with automated interpretation? Well, when I started reporting ECGs in the hospital we had a

secretary who would type the reports on three carbon copies of the report. The report was filed away in an envelope and that was it. When the patient came back with another ECG, the secretary had to find the previous file, bring it out, put the new ECG in, then the report would be done by comparing all the different ECGs. The other aspect of automated interpretation, as you alluded to in your introduction, is to provide storage facilities, backup facilities, for all the ECGs that are recorded. Now there are many, just for ECG, very helpful ECG management systems available. So that's another reason that the computer is of great value nowadays. It's not only one minute to report an ECG, it's something like 50 ECGs per second is the rate at which a computer can analyze ECGs nowadays. I'm not sure if I've picked out all of the points here, if there's anything you want to push harder on or...

Dr. Kashou: No, I think you answered it right on. We have all these tests we we generally accept and I think the ECG should also be considered another diagnostic test. Part of having this diagnostic test means you know where its limitations are, where its strengths are, where it's sensitive, where it's specific. Apart from the findings, but, you know, what does it do at baseline? As you mentioned, you know, the cardiologist, we go through all this training that we're expected to be able to interpret it competently. For other providers, maybe not so much. In fact, we're looking at this now, is what is the competency across different professionals with the computer, without the computer? Does it make a difference? I think you're right, the computer probably does better for some of those that are less experienced or don't have formal training or not seeing ECGs every day. I think we're now...

Dr. Macfarlane: Yeah.

Dr. Kashou: Go ahead.

Dr. Macfarlane: No, I was saying you're absolutely correct. I mean, there is the old story about two surgeons looking at an ECG and, "What does that represent?" And the answer is a double blind study. You will understand what's implied there. No disrespect to surgeons. I could pick maybe some other specialties as well, but definitely, the computer has something to add. The other point is, I remember, we started off maybe 15,000 ECGs a year in the hospital and now it's way above 30,000 ECGs per year. There's been an increased demand for the test and it's still one of the most widely used tests.

Dr. Kashou: Yep. With... As we were mentioning early on, apart from the software advances there's the hardware advances we're seeing and the new ways... Not that the signal's going away, but the way we actually record it is looking different where it's now out of the hospital recordings and what that looks like. But focusing on the software side and we see this whole artificial intelligence, these AI based models, really accelerating over the years, probably the last five to 10 years. Where do you see their potential role? We don't have to analyze one model per se, but where's the role? Where are the limitations and where are the benefits with this technology?

Dr. Macfarlane: Well, I think one role that they will have is using machine learning techniques. Where conventionally you may say you're going to report an abnormality of variable A is above a threshold, variable B is above another threshold, and variable C above a third threshold and

you play around with these thresholds, manually experiment and come up with what you think is the best. But machine learning, one of its forms, I think will be doing that much better than the human playing around by adjusting these thresholds manually to try and get the best sensitivity and specificity out of the criteria. That's one side of AI. The other side, say, more the deep neural networks, where the complete ECG is pushed in and out comes an interpretation at the far end, nobody's quite sure how the interpretation was made. The concern I have there is that there are a lot, as far as I can see, of false positive results. In other words, the positive predictive value is not very high. Now, if that's the case for multiple interpretations of the ECG, multiple different types of interpretation, induction defect, a myocardial infarction, et cetera, then you're going to have a very high probability of each ECG report coming out with an abnormality. That was the criticism of automated interpretation when it first started: far too many false positives. That has gradually, over 30 years, diminished. It could well be over a much shorter time, interpretations are AI based... deep neural network based will have an improved positive predictive value, but that's one of the dangers that I see from it at the minute. But it'd be foolish to say that in fullness of time there will not be some improvements in that respect.

Dr. Kashou: Yeah, you mentioned a lot of good points and how do we change almost what is that threshold and how do we improve that to maybe risk stratify patients that need maybe a next step or a next test to further clarify underlying disease, but-

Dr. Macfarlane: Well...

Dr. Kashou: Go ahead.

Dr. Macfarlane: Clearly, a good training set where the patient, the illness or what have you, is very well defined and use that as a training set and hopefully the machine learning techniques will give you the... essentially give you the optimum thresholds. May not be a part in use of what they are, but the process will do that. The other area that I skipped over and I should have mentioned is where the ECG is used to report or comment on a feature such as abnormal heart contraction or left ventricular diastolic function, for example. That was probably unheard of years ago, to have an ECG make a of left ventricular dysfunction, but definitely there is a trend in that direction. That's another area where the basic 12-lead ECG is still required, processed in certain ways, such as using wavelengths. Information coming out of that is then fed into a machine learning algorithm, for example, and you can have a diagnosis of left ventricular diastolic dysfunction for example, output. That's another thing that's going to expand, I think, in the years to come.

Dr. Kashou: With all these, obviously we can clearly see limitations and... You mentioned building out these models in a great data set, high quality, high fidelity. The other question is generalizability across different places. There's a lot of work with all these models and how we apply them. Does it change with the different hardware devices? The one question I have for you, given your background and history with the evolution of this device for so long, will this technology eventually become commonplace? What do you think of the adoption into medical practice? We mentioned non cardiologists. How are they gonna take some of these? Do you have any thoughts on that?

Dr. Macfarlane: I don't see any... I don't see any resistance to it if it's proven, but the accuracy of the technique is acceptable. I mean, we talked earlier about accepting blood results and not really bothering about what equipment is there in the corner that's produced these results. Nobody in any hospital could say that such and such a company's equipment and such a, such a process is what is used in the back room. The ECGs, I see in the same category. If someone gives you an ECG report at the minute and you're able to look at it, read it, et cetera, et cetera, you're not too bothered. "Has it come from a standard 12-lead ECG program? Has it come from an AI based program?" If it's been shown that the latter, for example, is every bit as good as the former. That's the way I would see it. You drive a motor car, but I couldn't tell you ins and outs of the engine that's inside my car; no way. But doesn't matter, I'm quite happy with the car. I've no doubt the engine has changed in design over the past 30 years. My car's a wee bit... Well it's not 30 years old. No, but the engine, changed over 30 years.

Dr. Kashou: Well that's-

Dr. Macfarlane: So, I see the same for ECGs.

Dr. Kashou:... quite fascinating. Yes. When you think of the car, and maybe it's just better understanding the diagnostic tool across medical professionals, realizing like we mentioned, the limitations: the car is not gonna fly, the ECG's also maybe not gonna be perfect either, right?

Dr. Macfarlane: Yeah.

Dr. Kashou: And so it's like know what to expect from the tool you're using and maybe that will give maybe better appreciation of what it actually can provide; seems more of a realistic approach that maybe we should try to adopt more often.

Dr. Macfarlane: Sure.

Dr. Kashou: Yeah.

Dr. Macfarlane: Yeah, no, I would agree with that.

Dr. Kashou: Yeah.

Dr. Macfarlane: Yeah.

Dr. Kashou: Now, as frustrating as ECG interpretation might feel to many medical professionals, it doesn't look like it's going away. Computerized ECG interpretation software has not only helped many inexperienced interpreters but has also become an important aspect in improving our clinical workflow. The future of electrocardiology appears bright with many developments that await us and many barriers to overcome. Professor Macfarlane, thank you so much for joining us again. It's always a true pleasure to speak with you. I know I always learn from our conversations and we are always grateful to have your unique perspective on these topics. Thank you again for joining us.

Dr. Macfarlane: Well again, thank you for the invitation. Always very happy to talk to you.

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