Computerized ECG Interpretation Software

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 are so glad you could join us. Today we have an exciting episode in which we'll dive into computerized electrocardiography. Looking at the development of the field and the end impact on clinical practice. We have the privilege to be joined by an expert who has witnessed firsthand, and has been a major part of the advancements in computerized ECG software. Before we get started, I'd like to introduce to you, my co-host Dr. Peter Noseworthy. Dr. Noseworthy is a Professor of Medicine and Cardiac Electrophysiologist. He serves as the director of the Mayo Clinic, Heart Rhythm and Physiologic Monitoring Laboratory. Dr. Noseworthy welcome, as always I'm so glad you are joining us.

Dr. Noseworthy: Thanks a lot, Anthony. Great to be here.

Dr. Kashou: Now, before we get into our discussion with our guests, let me give you a little bit of background on the topic to set up our discussion. Since the first human ECG was recorded by Waller using a glass capillary electrometer in 1887 in early recordings by Einthoven using a string galvanometer in 1903. The clinical use, the means to interpret and the ability to record cardiac bio signals have continued to evolve. In the 1950s we saw an important breakthrough advances in amplifier technology led to improvement in the resolution and quality of recording EKG signals. The first analog to digital conversion system made its appearance in 1959. And it was only a couple years later that multiple investigative groups were converting ECG signals from analog to digital data. Computerized electrocardiography made its presence known and has only continued to advance. Computerized ECG software has helped with ECG interpretation. It's helped improve clinical workflow and advanced our understanding of electrophysiology. In fact, it is likely one of the main reasons that the EKG has maintained its prominence as a diagnostic tool in medicine today. Today we're going to dive into this topic in much greater detail. We're gonna look at one how computerized ECG software has developed over the years. Two, we're gonna look at what the process looks like to develop new computerized ECG algorithms. And finally, we're gonna look at what the future of computerized electrocardiography looks like. Dr. Noseworthy would you please introduce today's special guest.

Dr. Noseworthy: Great, it's my pleasure. Today we have Ian Rowlandson, who's a biomedical engineer at GE Healthcare and he's been a pioneer in the field of computerized electrocardiography for more than 35 years. I've actually gotten to know Ian over the past several years through various collaborations. But he's been working with folks at Mayo Clinic since the 1980s. And I should note that GE is our vendor for ECG technology. Ian holds over 45 patents. He's developed a technology that we rely on daily for automated recognition of myocardial infarction, and serial ECG comparison. As well as some work he's done recently on the

prediction of sudden cardiac death. Ian is currently leading the Clinical Strategy and Diagnostic Electrocardiology at GE Healthcare. And Ian, thanks so much for joining us today.

Ian: Thank you for having me.

Dr. Kashou: So Ian, one of the main things is you're our expert, at least amongst us here today in this computerized electrocardiography field, where it's gone and where we are today. And maybe you can kind of take us through your journey from kind of where you saw it when you came into to, maybe how you got involved in the whole process.

Ian: Well, I entered into computerized electrocardiography in 1979 at a company called Markell Electronics, which was eventually acquired by GE Healthcare. But the problem in 1979 is yes, the signal was being digitized, but it was at the main computer. It was actually a mini computer. And so the signals would come in over the phone lines at three channels at a time and be digitized at the main system. And then the analysis would go on there. And actually that was also being done at the Mayo Clinic, with the Mayo program. And what we did is we started digitizing at the electrocardiograph, which enabled us to do all the sampling at the electrocardiograph and then send it digitally over the phone lines, which took a longer period of time. But now you had all 12 views simultaneously. You weren't looking at three leads at a time. You were looking at all 12 leads at a time. And that improved a lot of basic measurement, especially accuracy, because you could see that one beat that's in leads one, two, and three is the same beat of a different shape in V four, five and six. And so there were a lot of technical challenges of transmitting that signal digitally, which I got involved in and that included data compression. believe it or not the phone lines were so slow that we had to first, the first kind of challenge was could you get it down to a reasonable size so it didn't take minutes and minutes and minutes to transfer to the system.

Dr. Kashou: Was it the compression important because you were going from now three to 12 leads? Is it the additional data that was the issue or what.

Ian: Yeah, there was a lot more data. When you look at an electrocardiogram as a human you're not looking at everything the computer sees. Most people are looking at four by two and a half second records, but that's what we call it. With a rhythm strip at the bottom. We're looking at, the computer's looking at all, all the leads, all 10 seconds all simultaneously. The digital modems back then were incredibly slow. We're talking like 1200 baud, 2,400 baud, which was 240 bytes per second. I mean, that's pretty slow. And if you've got 40,000 of, or 80,000 bytes to send now what do you do? It's too much too much to send down the tube. So you have to figure out how to compress it, how to make it smaller but maintain the fidelity of the signal.

Dr. Noseworthy: We all rely a lot on the automated ECG interpretation software that you and others have created. It's really hard to imagine ECG without that in many practice situations. I wonder if you could take us through that process a bit on how that process has evolved over the years, and whether you think it's likely to continue to improve with current technologies.

Ian: Well, I don't know how far you want me to go back or, or what to touch on, but I really was around when, things like you had labels, sticky labels, you had printouts that, the workload in terms of actually getting the recording done was amazing. Sending out the electrocardiograph,

sending it back, having a report generated, having a sticky label, adhered to, and everything was done like on typewriters. So what happened was the electrocardiograph, computerized electrocardiography streamlined that processed considerably. Certain parts of that are still very well relied upon today, is the name on the report. Are the measurements which people rely on like QT on the report and automatically measured. And then we did the automatic interpretation too, but there was just a lot of, sort of, basic, house cleaning I guess, of electrocardiography that was just a mess. We do, I think at Mayo, you just do what 800 ECGs a day.

Dr. Noseworthy: Sometimes it's more, especially if you think across the enterprise. And I think we're probably not alone in having a relatively huge volume. The other thing that you've contributed that I think is really valuable is the ability to compare between ECGs, and especially once you are performing serial ECGs within an institution, and those things are archived annotated. The software that allows you to compare between, I think is very valuable. Do you wanna talk a little bit about where that idea came from, and what information we get from serial ECG comparison?

Ian: Well, Dr. Ralph Smith at the Mayo Clinic was a big proponent of serial comparison and sort of viewed it as a basic standard of care. That's a good thing, because especially now many years later, electrocardiography is so inexpensive, that you, and noninvasive, you can take a lot of ECGs on a patient over a period of time and then compare them. And that by the way is one of the challenges that, that is different actually than when we first did it back in 1983, '84 with Dr. Smith. But that was a big, that was a big step because people didn't really know exactly how to compare a current ECG to the prior. In fact, there was a lot of debate should you just look at how the waveforms change and generate a special report where, you show the differences in the waveforms and don't generate an interpretation. It was considered extremely difficult. And Dr. Smith really helped me and all of us, I think, to break the problem down into you have different possible physiological states in the ECG. First checkout is the current and the prior in the same state, before you start trying to make all kinds of judgments about what's changing. And then in certain states like there's normal conduction, but you're concerned about a myocardial infarction focus on the ST segments, start making statements about those changes. And that by the way, I still, I actually think we're one of the few people that I know of that actually do that. Most statement comparisons, or most comparison programs rely on statements. And frankly, when you're in the vault in an acute myocardial infarction, you can have the same overall statement, there is a myocardial infarction. But the important thing to know is this the ST segment changing? If you've already treated and you see ST-elevation come back, well, did the thrombolytic actually work? So you get the drift.

Dr. Kashou: The dynamic changes in someone that, presented with acute myocardial injury maybe before, during, and even after which is a huge thing because prognostically and diagnostically. I guess when you talk about the serial EKG, and building out these ECG algorithms, what are common challenges that you faced ensuring that, what you're implementing maybe is clinically accurate or helpful for the clinician? And maybe you can talk about a little bit of the whole development process.

Ian: Well, let's deal with the first pass ECG first, as far as development, because I think it's easier to define that. So we have, let's talk about today versus maybe in the past. So today we already

have, let's say a standard of accuracy. So all we want to do is move that in the right direction and always recheck on hundreds of thousands of ECGs. Have you made a mistake? Have you made things worse when you tried to make other things better? And so we can use ECGs that are been overread by a cardiologist, or ECGs that are clinically correlated. Like we know they're troponin positive, and we try to improve certain aspects, let's say of recognizing acute coronary syndrome. And then you wanna see, oh, did you start, taking things that are obviously not at acute coronary syndrome and start making statements about it. I hope that gives you an idea of the process. We benchmark it. And thank God we have these large databases because we stored the data with a fidelity that could reanalyze all the data. It's always, our banks of data keep growing. I think the Mayo Clinic probably has I think 8 million ECGs online as an example. So you have huge stores of data and when you, and you can rerun the programs now, now it literally in minutes on that kind of size of data, and see what's changed. And that's really revealing and actually fun to find out what where you're making mistakes and how you can improve things.

Dr. Kashou: In terms of, I guess what are, have you found as kind of, you put these algorithms together and now the definition of maybe STEMI is changing their different, areas of capturing, acute occlusion MI that now people are proposing, what are kind of, what is a common diagnosis that's maybe difficult for some of these algorithms to capture? where do you see kind of the, the holes in some of these.

Ian: Well, I'm gonna probably give you an answer in degrees of difficulty. So the human has a problem with left ventricular hypertrophy in STEMI for example. The human has a lot of false positives because they find ST-elevation due to the secondary re polarization of LVH. In V one through V three they see elevation, they get fooled by that. There's other common. And this is well documented by a number of people have done really a good work on this as to how the human can get fooled. And some programs don't even attempt to try to do a STEMI in the presence of left ventricular hypertrophy. We think you have to, because the prevalence of hypertrophy is huge. And hypertrophy has a certain pattern. Or rather, the re polarization has a certain pattern associated with it. That literally we look at vectorially as to which direction is it pointing and a STEMI points in a different direction, all together unique. And so we're looking at those forces, really three dimensional space to figure this out. So that gives you, I hope that gives you some idea, but there's some, let me give you one proximal occlusion of the LAD that is another problematic because, people want to intervene on that, but it doesn't generate ST-elevation in the same way. It's usually ST-depression throughout. And how do you find that as being unique signature of that problem, versus other forms of ST-depression? And I would say that's an area that we should be working on more. And people should be aware that you can have proximal LAD occlusion that doesn't really generate ST-elevation. But it is a STEMI of sorts.

Dr. Kashou: Did you think of, you talk about LVH and the strain pattern, the same thing with a right bundle the R prime in. We're expected and taught to say discordance is kind of an expected feature, concordance suggest ischemia but, at the same time the relative degree of discordance to that R prime is probably also important just like the sgarbossa criteria.

Ian: I think the thing about electrocardiography, and this is my opinion, and I think Ralph Smith and others have really, and some of the old really investigators is direction of the wave form. Direction of the force is much more important than the amplitude. The amplitude can get

affected by a lot of things. But if the forces, the cures, the initial middle end and the ST segment vectors are not aligning in the right directions or in this expected directions like a right bundle as you pointed out. Yes, it has a re polarization abnormality, but of course you don't want a trip over that. But you can certainly find a STEMI in the presence of right bundle because it's not concordant with what you expect.

Dr. Noseworthy: A lot of the ECG interpretation software is based around the concept of taking known criteria and applying them to the ECG. So the things that cardiologists do to identify LVH or to identify myocardial infarction, particularly in these complicated scenarios you're outlining, But in the current era, we have technologies to look at a phenotype and do simple, basically correlations between wave forms and an actual gold standard. And in doing that, it would change the task of ECG interpretation from one of applying set criteria, and doing it with fidelity to one of creating increasingly more valuable models for an underlying diagnosis. That changes the focus of ECG interpretation, especially with automated criteria. I'm thinking about mostly the application of AI. Do you think that's a valuable way for these kinds of software to go, or does that create a problem where a clinician essentially can't override the computer because the findings that are being applied are not necessarily obvious to the ECG interpreter?

Ian: Well, I think you're skipping ahead a little bit. So let me just actually emphasize that, take STEMI as an example. When we started working with Doug Weaver on the Mighty Trial and computerized electrocardiography was now put in an ambulance, the wave forms were not what we expected to see. We were catching infarcs way earlier than what people had seen. And the conventional kind of wisdom of looking at ST/T ratios and convexity and concavity and all that just didn't work. And so we were already looking at troponin positive, or maybe back then it was CK-MB positive ECGs, and then trying and clinical outcomes and looking at what these patterns are. And the computer actually said, I can separate these groups much better by looking at reciprocal depression, namely is there elevation and depression in the same ECG. And people knew that was a characteristic of a STEMI, but they had no idea how impactful it was, how much it increased your accuracy. So here was an example where we took computerized analysis and moved that it ahead with clinically correlated data. And improved the recognition and improve the knowledge. I think a there's a lot of papers now written on how reciprocal depression identifies people who are most to benefit from revascularization in the presence of a STEMI. So we were already there quite some time ago, where we were looking at clinical correlations and, and trying to make a better job than what the human conventionally thought. Now we're in an area where we're even beyond. Some of those STEMIs a human would say, oh I can see that across the room. It's just, I didn't tell you that, reciprocal depression was a better way to, to figure this out. 'Cause I wasn't aware of it myself. That's one of the things that's interesting about human beings, is they can actually see patterns and not be consciously aware that they're actually seeing it. It is one of the most, challenging and fascinating things about this work. Is you have to spend enough time with people to first figure out what are they looking at? And sometimes they are completely unaware and that's where the computer can actually sift out. What are the features that these people are seeing that they may not consciously really see in there at least to express to somebody else. Now we're in an age where I'll give you a controversial one at least to echocardiographers, is that, electrocardiography could actually detect aortic stenosis. You wouldn't think this would be so, but there's already been indications for quite some time that the ECG has certain features to it that would at least tell you the prior probability that that person has

aortic stenosis and needs to be confirmed by an echo. So now we're in a world where, and this is really rich and exciting is to take, because the ECG, as we were started out this whole meeting is done in such large magnitudes, I mean 800 people a day come into the Mayo, have an ECG somewhere in the system and they're having a variety of reasons. Can you go back and mine that data to find people who really need further evaluation. I don't know if that answered your question, but we're definitely on that cusp now and anticipating and anxious to, to work hard on how do we take this other information and integrate it into computerized electrocardiography. By the way, let me actually mention one other thing about AI or computers after being in this business a while, you should spend as much time worrying about how you present the information as the quote algorithm or the machine learning tool that figured out that there was a pattern. How you describe it, how you present it to the average physician is a matter of, will it be a accepted at all, or completely rejected? There's been a lot of really accurate algorithms that have ended up on the floor. Because they were never really integrated into the product properly. You have to really worry about that.

Dr. Noseworthy: That's fantastic to hear that perspective. Thank you very much for that.

Dr. Kashou: It's amazing, you're going from a tool that, relays these cardiac bio signals to giving us a diagnostic. And now, as you mentioned aortic stenosis, some of these other structural heart disease that, we still rely on the echo as our gold standard, but now can it actually change the way we manage patients? Could it push just in a way that maybe, some patients should get an echo and not. I know there's a lot of ongoing stuff here with AI, but I think you raise a really important thing is that there are inherent limitations with AI, and whether it's accepted and really understanding what it's seeing, but I know that it's a really active area of investigation today.

Ian: One of my favorite favorite topics is left ventricular hypertrophy. Because most people think of the gold standard being echo and that's it. It's LV massed and that's it. And now that we're getting into AI and looking at these correlations and the, the ECG is measuring a different aspect of the disease, which may have nothing to do with LV mass. And so it really, it's not only just doing a better job of, trying to find these problems, but creating new interest in the problem that needs to be investigated. Why is it that voltage increases in at least, in some people, when they have left ventricular hypertrophy is that due to increased mass or is it a conduction problem? And is the strain the ST segment deviations that you see in the presence of LVH, what is that? In fact, it's amazing we still really don't know exactly why it comes about. But my hypothesis is that more and more is related to that being a conduction abnormality delay in conduction due to the left ventricular hypertrophy.

Dr. Kashou: It's really an interesting thing. I know we're not anywhere away from losing this important tool. Computerized ECG software has aided an ECG interpretation, improved clinical workflow and advanced our understanding of electrophysiology. With the recent advancements in computational power. It is evident that its capabilities are only improving. And as you heard right here, it's important in clinical practice is here to stay. Ian, what an incredible impact you and your team have had and continue to have on the field of the computerized electrocardiography. I'm excited to see what the future holds. On behalf of our team, thank you for taking the time outta your day to join us. And thank you, Dr. Noseworthy. It's always a pleasure to have it and share this stage with you.

Ian: Thank you, look forward to the future.

Dr. Noseworthy: Likewise, thanks a lot Anthony.

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