**Reduced Lead Setting for Diagnostic ECG Interpretation Using Deep Learning Models**

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Dr. Kashou: Welcome to Mayo Clinic's ECG Segment: Making Waves. We're so glad you chose to join us. Today we have an exciting episode planned for you, as we discuss reduced-lead ECG analysis. Over recent years, data-driven machine learning models have shown promise for ECG analysis. Many models use the standard 12-lead ECG. However, are all 12-leads necessary? Today we are fortunate to be joined by Dr. Joel Xue, as we look at what reduced-lead ECG analysis is, it's clinical value, some of its challenges, and how it compares to standard 12-lead ECG analysis. Dr. Xue is currently leading the AI group of AliveCor, and is an Adjunct Professor of the Bioinformatics department of Emory University. Prior to that, he had been the leading algorithm scientist at GE HealthCare for 28 years. He holds many patents, and has published extensively in the field of machine learning, biomedical signal processing, and pattern recognition, especially as it pertains to ECG analysis. Dr. Xue, thank you for joining us.

Dr. Xue: Thank you, Dr. Kashou, it's so exciting to be here, good opportunity to discuss this very interesting topic.

Dr. Kashou: I've been looking forward to this, and you know, I think before we dive into the topic in detail, which I know we will, maybe you could start by giving our audience an understanding of what reduced-lead ECG analysis is, and what clinical value it offers, because I've learned a lot of this from you.

Dr. Xue: Thanks. So here I give kind of a broad definition of reduced-12-lead. Here I emphasize, there's a lot of reduced-lead analysis but this is more for reduced 12-lead ECG, so which is a topic for mainly we gonna focus today. So it's basically gonna involve using fewer leads than the actual measure standard 12-lead, which include the six limb leads and six precordial leads. Also known as diagnostic resting ECG analysis. And we are gonna do this reduced lead, and still performing similar diagnostic interpretations. So this method offers a main clinical value of simplifying the lead hookup process, and speeding up preparation and detection and also making the ECG device more portable for ambulatory use as well as facilitating patient management during patient monitoring situations.

Dr. Kashou: So the clinical value, you know, you could certainly see that there, and it does make sense, you're taking the 12-lead, and reducing it to perhaps some of the more important aspects, or the things that, and you'll share with us more, but before we get into that, I wonder what are some of the main challenges for this reduced-lead ECG analysis approach?

Dr. Xue: Good, so historically two main types reduced 12-leads has been tried. And the first approach involves a select subset of the standard 12-Lead ECG. For example, they using lead 1, 2, V1, V5, and another one use lead 1, 2, and V2, V5. And then they're using this measured leads to synthesize other precordial leads. So one advantage of this method is that it include at least eight leads, six limb leads and two V leads, that are the same as the standard 12-leads. So the second approach involves designing a completely new set of lead positions for the measure leads and then synthesize a 12-lead ECG from those leads. So that example is including the famous easy lead from Phillips. The one advantage of this method, is that the lead position are relatively easy to identify on the body. For example, it's left or right, up and down on the torso. But this method might result in the generation of relatively new 12-lead ECGs maybe not familiar by the physicians. So there are primarily two challenges associated with this reduced-lead method in the past. The first pertains to the accuracy of the synthesized leads compared to the actual measured leads. So the synthesized model typically used is known as called a global model. So meaning a set of conversion coefficient is applied to all patient ECGs. So the accuracy of this conversion model is limited not only by training data and also by that range of patient body size, body to heart geometry and also by a physiological ECG source model for instance a localized ischemia or myocardial infarction may not be synthesizable from another plane that cannot see or at least not accurately reproducible for visual interpretation. And the second challenge as this method attempt to use the same ECG criteria as the 12-lead ECG for interpretation, whether by algorithm or by physicians, as no set of criteria actually has been specifically developed for each reduced reset. However, due to inaccuracy in the synthesized leads caused by the aforementioned reasons, some compromises in interpretation performance cannot be avoided. For instance, easily leads detection of inferior ischemia MI can be affected by imprecisely synthesized leads.

Dr. Kashou: And so you could see these challenges of using this novel approach with the reduced lead. And I must ask, because you know we're kind of seeing this almost a renaissance in the whole field of electrocardiography in these new deep learning approaches can deep learning models be applied to these reduced lead ECG analyses?

Dr. Xue: Sure. So that's actually the focus of technical things I'm talking about today. So, you know the deep learning new networks model has been applied to many testers related to ECG signal analysis in the recent years. For the DNN model we're building the input can be either ECG waveform data such as reason data or the average medium B data. But however, whenever the requirements always see expanses for using data model is needing relatively large data sets. Here, thanks to our collaboration with Mayo Clinics and Emory University, we do have access to relatively large ECG database for this research. For example, we have 2 million ECGs from Mayo and 1.3 million ECGs from Emory, but our model training is mainly Emory datasets because they're more diversity of the kind of race and different patient demographics. So in our reduced research project, our aim is to solve the two main challenges previously just mentioned. First one is lead synthesizing in accuracy and the need for a specific set of criteria. So we aim to find the best resets that not only generate the most accurate synthesized lead but also provide the best ECG interpretations for major normal and abnormal determinations, especially on the morphology side such as left bundle branch block, right bundle branch block, ischemias, myocardial infections and so on. We have built a unique DNN model for each reset and trained them using the supervised learning for multi-class morphology determinations. It was almost impossible to carry out such tasks before since even building one specific criteria for a select lead set had not been done. We have built a total of eight reduced reset models, four using two limb leads and one precordial lead and four using two limb leads and two precordial leads. Each model was also trained with a result synthesized lead. Our results showed that the best overall combination of two limb leads and two prerecord leads are lead 1, 2, V2, V4 and lead 1, 2, V1, V4 for this later one because V1 actually carries the best QA information so can get overall better reason interpretations. So one key take takeaway from the study is that reduced reset results synthesized leads can perform equally or better ECG classification of all the four determinations when compared with the reset that adds synthesized leads. This is important because it can reduce one layer of error if we do not need to involve synthesized leads for DNN model classification. However, synthesized leads are still needed we think for review purpose.

Dr. Kashou: This is really fascinating. And so are you saying that the reduced lead performances how do they compare to, you know, the standard 12-lead ECG? Is it better, worse, or have you looked at that?

Dr. Xue: Yeah, we did carry the some scope for the major morphology and the reason determinations. So our first task was to compare the STEM 12-lead ways to select reduce reset, which we finally come down to two we just mentioned. So V2, V4 and the V1, V4. So both train with DNN models and with some post analysis using the same interpretations as labels so the results show that reduced leads perform as well as the full 12-lead for almost all determinations with only the LVH interpretation slightly better in the full 12-lead. So here we compare both model also built with 12 leads. The next, our second task is to compare the final interpretation performance of a reduced lead with the established 12-lead analysis program such as GEs trial cell. So which is a mainly expert system based algorithm as we know does myself involve quite a bit of endeavor. So the major morphology, the recent determination of reduced reset were found to be mostly equivalent to 12 cell although 12 cell definitely has a more complete list of a determination like more recent modifiers.

Dr. Kashou: It's very fascinating to see that and I think that comparison will be important. Where do you see, you know this reduced lead ECG analysis is quite fascinating. Where do you see it going next? Is there any clinical use? What's next for this?

Dr. Xue: Yes. So here in AliveCor, again with the collaboration with the different research groups our reduced lead device and algorithm shall be available for physicians to conduct clinical research and experiments very soon. But I think Mayo's already got one other prototype and we will also make sure one thing I also worry just working on this field for many years is how to make DNN model more acceptable by physicians. Cause usually we do have talkings that people view DNN model based algorithm as a black box but this is not actually entirely accurate. Just every unit and layers of operation are well known inside a DNN model. And automatic feature extraction part is also reflected in the final layers of the model. But to guide the behavior, the model we are adding some extra analysis such as P-wave detection for some recent analysis current duration for bundle branch block and ST level for ischemia and infarction. So, but our goal is to make the model analysis more transparent and understandable for physicians to use. So we plan to carry more clinical studies in hospitals including at Mayo Clinic and some other major medical center to test the application of reduced lead ECGs.

Dr. Kashou: Well you heard it here, reduced lead ECG analysis. It's really, you know coming and we're seeing a lot already the power that you've shown and told us today in the transparency of the models that you're really working hard to do. I think that'll help convey the trust that we want from all of our providers that are using these models to see. We continue to see the field of Electrocardiography advance especially as it pertains to the application of artificial intelligence techniques. We learned today about reduced lead ECG analysis, it's clinical value, some of the challenges that are coming about and what's next for this approach. Dr. Xue, thank you for sharing your expertise with us on reduced lead ECG analysis. It's really exciting to see what you, the AliveCor team and others are doing and what the future holds. On behalf of our team, thank you for taking time to join us. It's been a true pleasure.

Dr. Xue: Thank you. Thank you so much.

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