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The Mayo Clinic: digital health centre of excellence

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Professor Francisco Lopez-Jimenez MD, MSc, MBA, Chair of the Division of Preventive Cardiology and Co-Director of the Division of Artificial Intelligence in Cardiology at the Mayo Medical School, shares with Cardiopulse Digital how the Mayo Clinic became a pioneering institution in Digital Health.

The Mayo Clinic is a world-famous institution. Can you provide some background on the Mayo and cardiology in particular?

The Mayo Clinic is one of the oldest medical institutions in the Americas, providing medical care for >150 years. They credit it with the invention of the unified medical record and the creation of the integrated multispecialty medical practice, where doctors with unique skills provide care in the same physical location. This is ubiquitous in modern medical practice but did not exist in the mid-19th century (*Figure 1*).

Mayo Clinic employs over 60 000 people and has been voted as the number one health care facility in the USA for several years. The slogan 'the need of the patient comes first' is really at the core of our daily practice. Our cardiology department has over 150 cardiologists on staff in Rochester, with three other cardiology groups in other geographic areas as well. We perform over 250 echocardiograms and over 1000 electrocardiograms (EKG) a day. Our cardiology department has been nationally recognized not only for the premier clinical care but also for the scientific productivity and the many educational offerings including seminars, courses, and continuous medical education programmes offered every year. These are the three 'shields' that characterize the Mayo Clinic logo: patient care, medical education, and research.

As a cardiology department, you are very active and productive in applying artificial intelligence (AI) to improve cardiovascular care. Why and when did you decide to start this?

We have been doing AI since around 2015. The merit truly goes to Dr. Paul Friedman, the current department chair, and to Dr. Zachi Attia, who came to Mayo several years ago as an engineer looking for additional expertise in biomedical sciences. Together, they developed the first AI tool in our department, one aimed to detect serum potassium levels using the EKG. Soon after that, I joined them and, together with another few colleagues; we started working on a large project trying to detect low left ventricular ejection fraction using AI-enabled EKGs. This resulted in several seminal publications that expanded into other disease conditions and objectives as biological age prediction using EKG. Awareness of our programme and research using AI and EKG boosted the growth of our group.

You have published much on the use of AI for EKG analysis over the past 2 years. Where do you see the opportunities to implement these developments clinically?

The EKG is a simple and universally available technology existing for over 120 years, with minimal changes reflecting its robustness to detect cardiac abnormalities from the very beginning. Our contributions and those of others to the field show we have not tapped the whole potential of the EKG, as every month we see new discoveries in disease detection using AI-enabled EKG analysis. There are different areas where this technology can apply to: first to detect abnormalities or medical conditions that were not being suspected. Second, to monitor or for early detection of silent or still asymptomatic conditions such as arrhythmia, long QT, potassium levels or myocardial infarction using point of care tools, or little devices that people can buy. As we expand our work into the mobile applications, we will just see more of such applications in people's lives. Third, there is also the opportunity for population screening, particularly with the goal of identifying individuals at risk of cardiovascular events who would otherwise go unnoticed, similar to universal screening for blood pressure, glucose, etc.

Besides EKG, in which other domains or targets do you see opportunities for AI (image analysis, clinical decision support, etc.)?

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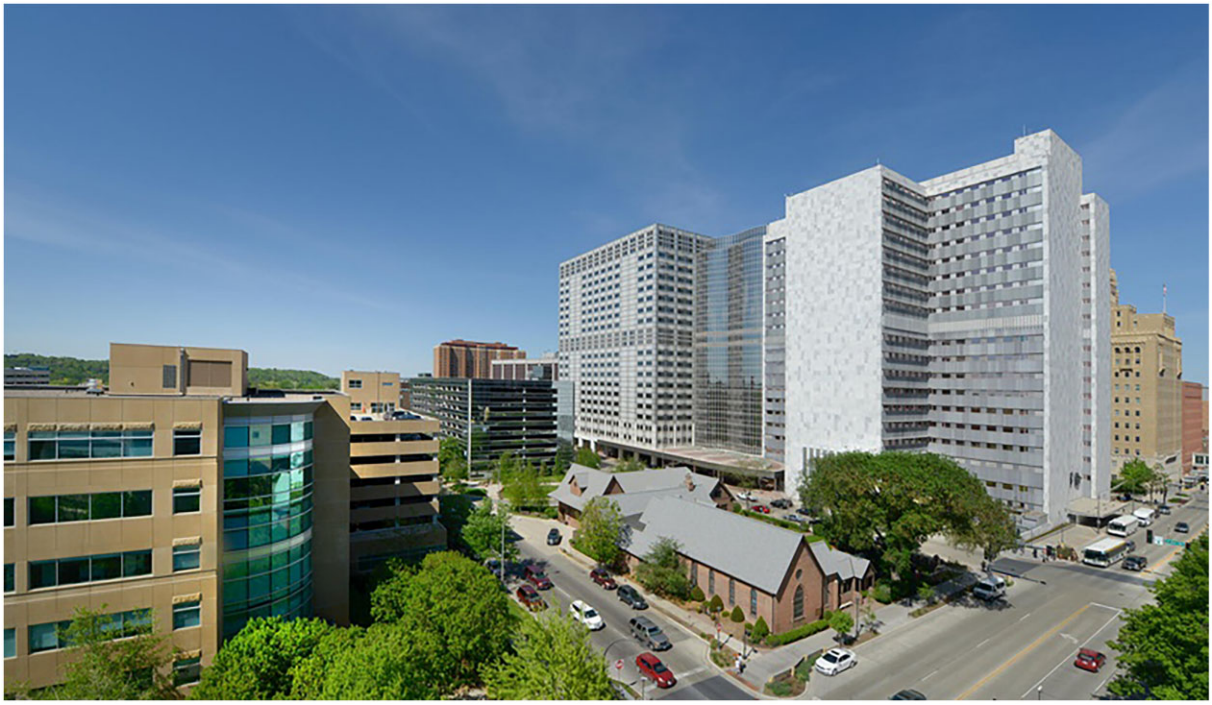

Figure 1 The Mayo Clinic.

Computer vision is an area that will see an exponential growth in the coming years, as there is significant interest in trying to optimize automated interpretation of different diagnostic modalities like echocardiograms, cardiac catheterizations, nuclear medicine, cardiac computed tomography, and magnetic resonance imaging. However, computer vision will probably go beyond automatic interpretation, as it will expand into pattern recognition to discover new applications going beyond what the human eye can see, and to identify diseases not easily recognized. For example, cardiac sarcoidosis is difficult to detect by visual interpretation of echocardiograms, but the computer might identify a particular echocardiographic patterns and provide an accurate diagnosis. This also holds for a coronary angiogram, a test that now is mostly limited to the description of the degree and number of obstructions, where AI may identify other factors like coronary elasticity, flow patterns, and even lesion or anatomical patterns unveiling prognostic or therapeutic implications.

There is definitely a substantial potential for applying machine learning into clinical decision support tools. All over the world we use electronic medical records (EMRs) that are not very intuitive, have a lot of redundancy and, most times, are very clunky. Clinicians experience significant burn out after incorporating the EMRs into their clinical practices. While the opposite was expected, the reality is that EMR did not make the lives of clinicians easier or patient's life safer. So, there is enormous potential incorporating AI in EMR, making those systems more intuitive, smarter, and decreasing instead of increasing the clinician's workload, improving clinical practice, reduce variability, minimizes medical errors and improves patient outcomes. Worldwide, there is a lot of interest in using AI in medicine. However, that is not that simple, not to say very complex. What is your secret to success?

Since the beginning, we developed an AI workgroup similar to an enterprise: defining goals, setting up a vision, mission, and defining the strategy. By strategy, I mean defining exactly how to get where we wanted to be and to define the necessary steps to achieve our goals, followed by action. We also defined the deliverables and how we would measure success. For example, we determined that in 1 year; we needed to grow by an amount in terms of scientific publications, new algorithms, intellectual property disclosures, patent applications, and other goals. We also decided early on that our goal would be to be part of the entire life cycle of an AI solution, going from the conceptualization of the idea to the commercialization of the product. This was not an easy goal, but we have been very fortunate to have multiple resources and teams available at Mayo Clinic, including the groups in charge of platform care, business development, the centre for digital health, among others, allowing our group to see how AI solutions can be incorporated.

Our strategy also included fostering interest in AI and talent recruitment, and the results have been amazing: we have over 40 clinicians or scientists in our department that are involved in AI projects in one way or another (*Figure 2*). We have currently six engineers working full time in the development of different AI solutions. Promoting education in AI has also been one of our original goals. Besides monthly AI seminars, we share with our distribution list interesting articles, readings, external conferences, and other educational opportunities. We actually created the first continuous medical education programme of AI in Cardiology in the USA in 2019. All this effort would have not been possible without the help of an

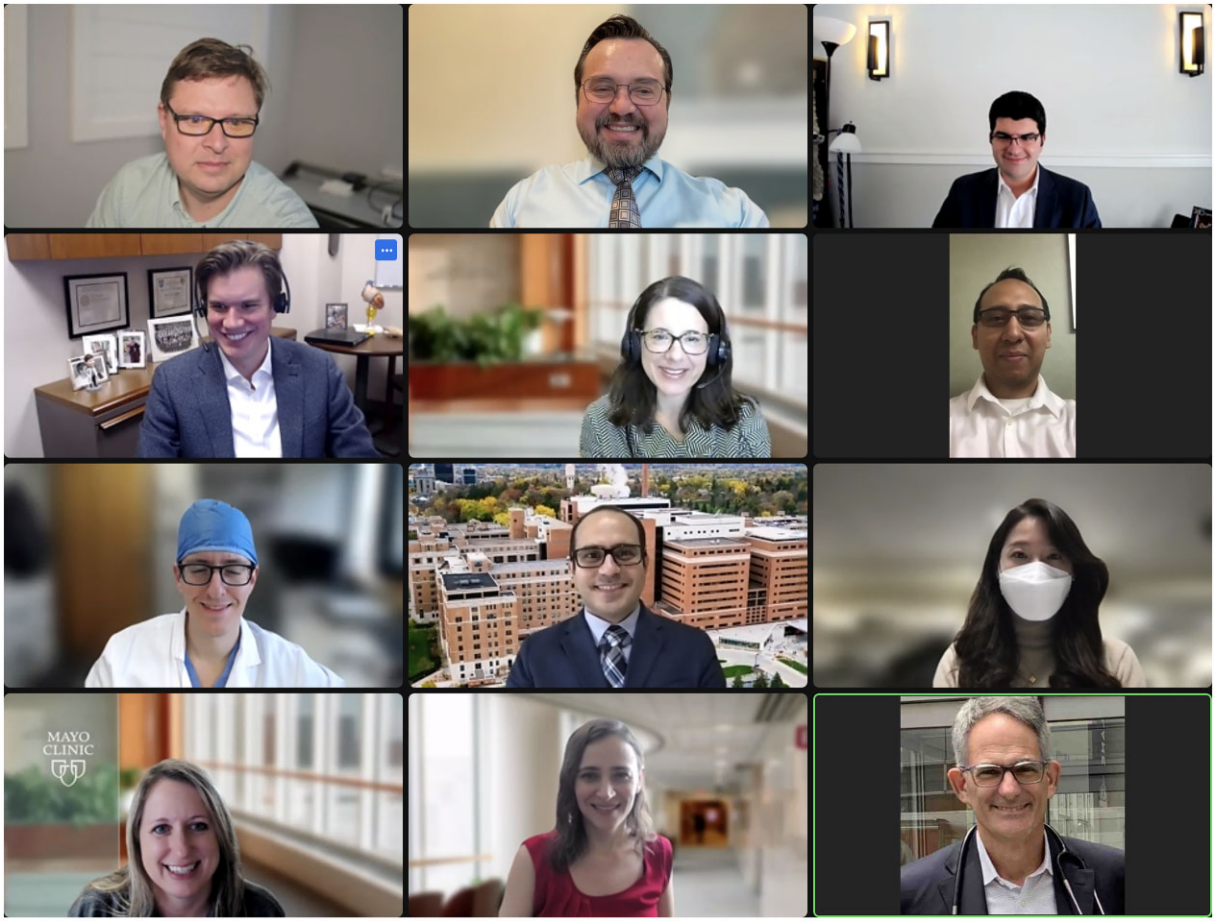

Figure 2 Names from left to right, top to bottom. *Row 1*: Rickey E. Carter, PhD; Francisco Lopez-Jimenez MD, MSc, MBA; Itzhak Zachi Attia, PhD. *Row 2*: Peter A. Noseworthy, MD; Jessica C. Cruz, MBA; Abraham Baez Suarez, PhD, MS. *Row 3*: Konstantinos Siontis, MD; Behrouz Rostami; Eunjung Lee, PhD. *Row 4*: Stephanie R. Daniels, MA; Jennifer L. Dugan; Paul A., Friedman, MD.

administrative partner or operations manager in innovation that is part of the core leadership of our group.

Do you see more Digital Health areas which can profit from your expertise and setup as implemented at the Mayo besides AI? What is your vision on what we call now the Digital Transformation of Healthcare?

Absolutely! The digital revolution goes beyond AI, as you have shown with the different great publications in *the Journal*. We see major opportunities implementing AI in platform care, integrating AI in virtual reality and extended reality, something that will facilitate medical education and remote care through virtual consults that go beyond just video chats. Mobile technology will continue to grow, incorporating AI solutions, and empowering patients to take care of themselves better through self-monitoring, smart chatbots and other digital solutions. AI-based mobile technology in medicine will make health care more scalable and ideally more fair, allowing physicians to reach the masses plus people living in remote areas, empowered by the universal expansion of access to mobile technology. Remote villages in Africa might not have basic urbanization but have mobile cellphones.

Although all this sound very exciting and promising, digital transformation needs to be conducted with caution. We need to be sure that whatever is deployed as an AI solution using platform care, virtual reality or mobile technology, must extensively be validated, tested in different settings and different populations, and proven to be valid. We need to ensure equality in access to/in health care and implement digital health appropriately. As excited as we might be during the digital revolution, cautious implementation will increase trust among clinicians, the public, and would be good for everyone.

Conflict of interest: There are no conflict of interest.