Use of AI for Complex Thoracoabdominal Aortic Repair and Endoleak Detection

Developing artificial intelligence models for precision medicine, use for endoleak and spinal cord ischemia prediction, procuring the right data and what to do if data are incomplete or missing, working within privacy laws, and making models available for "prime time" in practice.

With Kak Khee Yeung, MD, PhD, FEBVS

To start, how did you become interested and involved in artificial intelligence (AI)?

My interest in precision medicine began about 20 years ago, and my interest in AI followed about 10 years later. It started with a simple line of questions: Why do patients develop aneurysms, and why do some aneurysms grow while others don't? To try to answer this, I used a biobank, which has deidentified data and imaging together. We started longitudinally collecting data and working with in vitro models, trying to connect cellular data with imaging. At the time, I could only perform correlations, not predictions. AI soon became more of a hot topic, and I realized that this could be used to connect my data in a more usable way.

What is the scope of your current work in developing AI for delivery of precision medicine in the form of personalized aortic care?

Currently, patients with abdominal aortic aneurysms (AAAs) and peripheral artery disease (PAD) are managed based on guideline recommendations, which are derived from data from large populations of patients. However, predicting when an aneurysm will rupture is still an unknown—for example, one patient may have an 8-cm aneurysm and no rupture, while another patient experiences a rupture at 5 cm. We can come closer to a prediction if we look at not only the imaging but also other predispositions. In the VASCUL-AID project (www.vascul-aid.eu), which aims to identify patients at high risk for AAA growth or PAD progression, we use an AI-driven platform to look at genomics, proteomics, and lifestyle data from wearable devices to look at heart rate and physical activity, as well as imaging and clinical data. In sum, we are taking a holistic approach to the patient so that we are making decisions not only based on imaging.

AI can help make multimodal prediction models to recognize patterns to see if the patient has a higher risk for cardiovascular disease progression. It can also discover new patterns with deep learning methods. Current research often does not have standard outcome sets or standard data dictionaries. With AI use, there's a need for data infrastructure to produce high-quality data.

Can you walk us through a potential patient workup, treatment decision-making, procedure, and follow-up plan generation using the personalized medicine approach?

In our personalized medicine approach, say we have a patient with a 4-cm aneurysm. We would then look at other risk factors for cardiovascular disease. We give patients a wearable device to track their activity at

home and look at their genes/proteins and clinical data. These data all go into the AI model, which creates a prediction. For instance, the model might note as advice: "This 4-cm aneurysm has a low risk to rupture and will be stable for the upcoming 5 years," or "The aneurysm will probably grow in 5 years reaching 6 cm, but rupture chance is low." Then, it factors in activity level. If the patient has low activity at home and is still smoking, the model will note, "Although the aneurysm is not growing, he is likely to develop cardiac disease." Next, it would be refined with any genetic or protein data, which might note, for instance, that the patient has a high risk for myocardial infarction in the short term. Then, physicians can look to make precise recommendations for management, such as tighter blood pressure control, and the patient can be referred to a cardiologist.

If the patient has a dissection, AI can make predictions that the disease is high risk but will either stabilize with strict blood pressure control or require thoracic endovascular aortic repair, followed by branched endovascular aneurysm repair (EVAR) based on the "digital twin" of the patient (ie, a patient with the similar proteins or genes, blood pressure, clinical data). These more precise predictions can help inform clinical decision-making.

How would endoleak prediction and detection work specifically?

Applying the model during surgery can help the operator with decision-making. We worked on a model for use during surgery to visualize type and extent of endoleak directly after EVAR. The model also can be used before or after surgery for endograft placement and to predict sac regression based on proteomics using inflammatory markers and imaging. Based on the model, you can get a prediction on when a patient will likely achieve sac regression and determine follow-up protocols for that specific patient based on this information.

We also obtain prediction of growth of the neck. Some patients have neck dilatation, a quick increase in neck diameter, or a very small neck diameter increase over time. You can anticipate a type I endoleak and adjust placement for an already placed fenestrated EVAR or put in anchors and know that postoperative follow-up is essential for monitoring.

How would the program work to predict the potential for spinal cord ischemia in a complex thoracoabdominal repair?

The model would predict likelihood of spinal cord ischemia based on the preoperative CT scan, visualizing the spinal arteries and the collateral network, but also use sarcopenia and clinical parameters that the human eye cannot see. If the patient is determined to be at high risk, this might prompt the decision to put in a spinal drain or stage the procedure. This can also help with discussions of the benefits and risks of the procedure with the patient.

What does a relatively complete patient data set comprise?

This is a good question because in AI, we don't know yet. Right now, decisions are made in collaboration with key leaders in Europe and the ethical team following the European AI Act. Europe has specific rules about the use of AI, and one is that you have to be inclusive of all populations and input data on gender, race, country, region, etc. Regulations must be followed; every data set collected needs to be retrievable and then is checked by the Ethical AI Commission to ensure that data collected are inclusive.

Other considerations include: Can you use all that data? How much data is enough? Are you collecting too much data? Can you collect faces (not in Europe according to the European AI Act)? These discussions are still ongoing, but your methods should be discussed with your AI ethics team to ensure data collection is justifiable.

What are the potential pitfalls of using AI and precision medicine if your data set is incomplete?

There are some AI models that you can use for missing data. However, it's not so much the completeness of the data but more the quality of the data that is very important. AI tools can be used to enlarge the data set, and if you have an algorithm and a prediction, then you need to validate them using an external data set. I would also advise to use an out-of-distribution filter for validation (ie, a check if your algorithm was made from data that are reflecting your patient).

Who owns the patient data, and what rights do/will patients have to manage their privacy?

This depends on where the patient data are being collected. Each country in Europe has its own patient privacy laws. Some countries do not require patient consent for data, others are very protective.

How has your group worked with the European Commission to develop a program for collection, management, and utilization of patient data for the purposes of algorithm development and individualized care?

The AI Act was recently passed in Europe, which establishes rules for the development and use of AI tools and systems. The European AI Act forbids any AI use in high-risk groups and use of any misleading AI tools, which

means that some AI tools that use neural language processing or facial data are prohibited. The VASCUL-AID project is sponsored by the European Commission and was designed as a framework for how AI tools are used in the medical field. We work together with our consortium partner ALLAI (a company that works on responsible AI use), and they advise us on what is feasible, what is not feasible, what is high risk, and what is low risk to comply with the European AI Act.

Once "ready for prime time," how will these algorithms become available to hospitals and practices?

There are different options. The algorithm can be licensed for companies to install and integrate the model within their data set. The algorithm can be open access and installed in your work environment by your information technology department. We have a few already publicly available. If you do not have the computer power, then there are options to share the data with us and we advise you from a distance. Or, you can apply what's called federated learning, where you bring the algorithm to the hospital and tap into data at its source. The algorithm uses raw data from the hospital's data set, the AI model is trained on that data, and predictions are generated. This requires a fair amount of computer power in your hospital. ■

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