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> **We have some amazing tools now, whether we're using large language models to collect data, view data, or pull everything together**

Q1 The theme of this year's European Academy of Allergy and Clinical Immunology (EAACI) Congress is built around a future free from asthma and allergy burden. From an asthma point of view, what would meaningful progress look like in this field in the next decade?

We have brilliant drugs and biomarkers that allow us to stratify patients for therapeutic response, but they're not perfect. They don't precisely match the patient's molecular phenotype, which is why, even after optimising the response population, we still only see complete remission in around 20–40% of patients. So, in relation to that, we need to find a signature or set of biomarkers that help improve that percentage. We know from previous works that if you take sputum and analyse it in depth (inflammometry), and direct therapy towards what's going on in sputum as a marker of airway inflammation, you can get up to 60% remission, which is much better than with current biomarkers.

But that's still not practical. So, we need something much more accessible, whether that's a blood test, a breath test, or a nasal sample, that's going to help us. And I think that this type of analysis is ongoing. Studies across Europe, including those I'm involved in, as well as collaborative studies between Korea and the UK, are performing multi-analysis on responder and non-responder populations for specific biologics. The question is, is there a biologic or molecular biomarker that can tell us whether a patient is more likely to respond to a specific biologic, rather than indicating they're likely to respond to biologic therapy in general, which is essentially what blood eosinophils and fractional exhaled nitric oxide tell us today. I think that would be the real transformation.

We will eventually be using deep metadata and AI to help define what combination of biomarkers and clinical signs is optimal for predicting the best biologic for each patient. Ultimately, we'll have algorithms that collect data as you

come into the clinic and quickly determine the treatment you need.

I'd like to see biomarker testing become almost as quick as COVID tests were, fast, easy, and simple. If we could test for four particular biomarkers, that would be really valuable. Blood would be the easiest, but you can readily take nasal swabs, as we did for COVID-19.

We can perform flow tests against most analytes, so if we knew what we were looking for, then I think that's something that would come forward because it's quick and practical. I also think we will get there by applying machine learning and AI to the data that we're collecting from these reasonably large responder and non-responder cohorts to biologics. We're not doing it in paediatrics to the same degree, so that's going to be a huge issue that we need to resolve.

Q2 We've talked about AI so far, and AI is expanding at such a rate that, from what I've seen, especially looking at the UK, often theoretical technologies outstrip the capacity in hospitals. They don't have the technology to actually implement these tools. Is the current landscape across Europe equipped to deal with these changes, looking towards biomarkers and testing these kinds of things?

I think it's exactly the same. We have some amazing tools now, whether we're using large language models to collect data, view data, or pull everything together. We're using graphical neural networks or encoders to look at data and identify hidden patterns. There are approaches being taken across Europe, as well as globally, which is essential, because this AI approach requires a large amount of data for training and validation. Most of the data that's out there so far includes small numbers of patients, and we're self-validating. We need to validate results in large independent cohorts.

We've done some interesting studies. For example, we measured lung function and pollution exposure in preschoolers and kindergarten kids, as well as teachers, parents, and grandparents. The question is, can we predict their lung functional changes according to the environmental pollution exposure? You get good predictive data using AI, but the numbers are low, and it doesn't reproduce when you go to another cohort. So, it's a good indication of what we could achieve, but the real limitation is the initial sample size for predictive modelling. Numbers are everything.

Q3 What are the limitations to rolling these practices out across Europe? You've already touched on data, but I wanted to ask specifically about access to it. Given that patient data is highly personal and subject to GDPR and other privacy regulations, how do you access the data required to train these AI models?

We, as a community, are getting away from what used to be 'This is my little data set, I'm keeping it for myself', because it's not our data; it's the patient's data. And the patients are quite happy to give ethics approval so that we can share it.

The large EU studies and some of the individual countries are saying that we must share data, make it available, and make it findable. You don't have to give it away, but you can make the types of data you have visible to anybody else and say, "Well, I'd like to validate my data set. You've got this data, can we collaborate?" So, it's going to be two levels. First, the data is findable, and then we have the personal interaction. Data sharing can create issues with GDPR. But I think we've got some good ways to perform analyses through cloud-based analysis, so we don't have to worry.

The only major problem currently is access to the huge data sets being generated in China. They have access to Western databases, but currently we can't use theirs. One option is greater collaboration, where we go to China and get them to do the validation or primary analysis. It used to be impossible to do this type of analysis, but it is a lot easier now.

Q4 We've touched on biomarkers and AI, but as the asthma section chair, looking ahead at the rest of the Congress, what other kind of developments do you think people should keep an eye on, either at the Congress or in the general landscape?

I have been thinking about the environment and how it impacts the incidence and severity of asthma. We know it has an effect, but what can you do about it? We understand that we can use it in prevention, but we can also try to lobby governments. One of the really great things that Japan has done, for example, is address the huge allergy wave that comes every year. Around 40% of Japanese people are allergic to Japanese cedar. Most of Japan was reforested after the Second World War with Japanese cedar because it grows

quickly. However, this tree is hyperallergenic and drives the seasonal allergy wave.

So, they are now reforesting with non-allergenic trees. To me, this is amazing. This is an example of what you can do. Thus, allergists are working with the government to change the whole landscape of the country. We have similar problems throughout Europe, although the allergen-driving trees, bushes, or grasses are different depending on which part of Europe we come from. That's something that I feel is within the remit of EAACI, and that we should be pushing for these types of societal changes. We'll need to get numbers by improving collaboration between registries. Working together with the national registries across Europe is one way to obtain data to highlight the importance of allergies in population health at local, national, and regional levels.

We have registries for allergies across Europe, but they don't work together as much as possible. We should join up these registries, and then we can say to governments that, for example, 40% of your voters have allergies. It doesn't matter what age they are; they have allergies, their children have allergies, and you need to do something about it. If you don't, there's an electoral issue. I think that's something we should be advocating for. I am very keen on getting registries coordinated so that we can really demonstrate the scale of the problem.

Q5 It's really interesting to hear about the intersection between public health and allergy. How important do you think that overlap is?

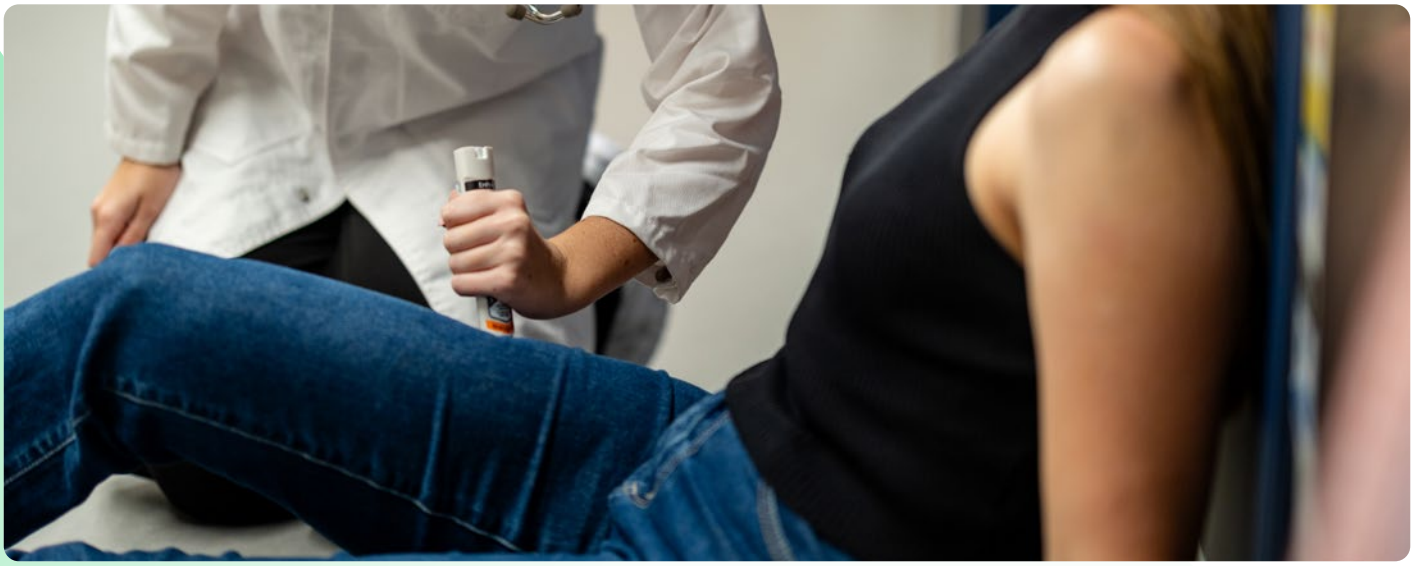
In the session I chaired today, we discussed how the gut microbiome affects allergic response. People are doing faecal transplants and taking 'poo' tablets, but that's not really the answer. There is a strong link between the gut and health, and if you understand that link, you will be able to find out what it is that the gut bacteria are secreting (e.g., butyrate or itaconate) and the effect on the immune cell community trafficking into the lung.

For undergraduate teaching, I use things like 'you are what you eat', and I get specialist dietitians to come in and talk to medical students, as it shows how much of an impact diet can have.

People say, "an apple a day keeps the doctor away," and there is real truth in that. I feel that there are social aspects that are really important to try and overcome to help us with the severity and incidence of asthma as well as other allergic diseases.

Q6 Are there any other examples of similar schemes or good examples of allergy prevention, similar to the example you provided from Japan?

I know people are talking within the UK government regarding allergy prevention, although not to the extent seen in Japan. The UK government does have a new National Allergy Strategy with stricter safety laws such as Benedict's Law, which mandates that all schools in England conform to comprehensive allergy and anaphylaxis training and keep 'spare' adrenaline injectors on-site. Furthermore, Natasha's Law requires all directly sold pre-packed foods to have a full allergen listing. In relation to asthma, there's the Committee on the Medical Effects of Air Pollutants (COMEAP), but they're only one of many voices talking to the government. They don't have a direct line to number 10



to change the policy, so they can only advise. We've made advances in some areas of allergic diseases and asthma in relation to the environment and related issues, but we need greater success.

You do get some local authorities that buy into this. It takes a lot of money to regreen some of the parks, plant trees or bushes where there weren't any beforehand, and try to change traffic flows near schools. So, on the local level, I think we're getting a little bit more traction in relation to low emission zones. However, nationally, we could do better.

Q7 Pivoting slightly to look at other aspects, there's been a lot of advances in treatments. Why doessteroid resistance remain such a challenge?

I think it's because the new drugs, biologics, are expensive, and they're not available to everybody. So, the default is 'we will increase the amount of inhaled steroids' as they are mostly cheap. If patients do not respond to these, oral steroids are another easy option. They are very cheap and are effective, but they have devastating side effects. If we don't know whether a patient will respond to inhaled and/or oral steroids, we risk giving increasing doses of the drugs to patients whose disease symptoms will not improve, but they will get side effects, including their bones crumbling away, or potential steroid-induced psychosis or paranoia.

For certain areas across the globe, this is a huge issue, because steroids are the only option available. If we cannot identify who will not respond well to these drugs, we may end up increasing the dose tremendously without any clinical effect. Alternative options could be bronchodilators in combination with other less powerful anti-inflammatory drugs. If patients are going to get side effects without responding to the steroids, we're doing the patient a disservice. Although the initial drug cost is

low, the societal cost is high due to the side-effects.

If you're in a low-middle income country and are indicated as needing to take steroids for the rest of your life, you are at risk of having a shorter and less productive life. I think, therefore, that understanding why steroid resistance exists, and how this may be overcome, remains really important.

There are some great studies from the Severe Asthma Research Programme (SARP), in the USA as well as in Europe, showing that Type 2 (T2) high asthma, reflected in elevated levels of eosinophils, is not the only kind of asthma. Patients with other types of asthma, including high levels of both activated eosinophils (T2 high) and neutrophils (Type 1 high) in the airway, have more severe disease that doesn't respond to steroids. So, could you, by targeting one aspect of that T2 or Type 1 inflammation, enable patients to respond to low levels of steroids? I think we still have an issue, and it's gone off the radar a bit because we have really good biologic drugs. This has now changed our perspective on asthma therapy from control to remission. However, despite the use of T2 biomarkers, a large number of patients do not attain full remission with anti-T2 biologics, and we use the same biomarkers for these biologics. Future work is needed in this area.

Q8 Looking outside of steroids and biomarkers, what are the pathways you think are going to be significant in future treatment?

I think we will start using nasal biomarkers more prominently as they're easy to collect. You can do it in kids: it's easy and it doesn't hurt. You can do RNA studies as well as protein studies. We're also starting to use machine learning algorithms to predict what's going on in the nose and compare that with, and even predict, what's happening in the airways. That's one way of helping stratify an asthma type, just by looking at the nose. I think that's going to be an area that will be advanced.

Of course, that's using standard biomarkers. We don't really work closely enough with biomarker companies, which is why we don't have that many biomarkers, which goes back to what I said earlier about lateral flow tests. If we identify specific targets that reflect asthma severity and/or response to therapy with specific cut-off points, we should be able to work with companies to generate simple assays. We probably don't need to do a screen on 20 biomarkers; you may just need three. You can just use a traffic light system to indicate that further assessment is required if your sample is more 'red'.

The other area that we will see improve will be imaging. That's going to give us a non-invasive insight into the lung. At the moment, most people are focused on mucus plugs. Can we see those? Can we detect them? Can biologics target this? Imaging will tell us more about airways and disease, and, in combination with impulse oscillometry or other non-invasive markers of airway physiology, will help us to better phenotype patients and detect responder populations.

We've been doing studies using multi-omics analysis in relation to some airway diseases and imaging to see if there is activation of particular pathways that reflect CT features or changes in the R5–R20 ratio. These types of analysis may give us an indication as to novel drug therapies for patients with

specific imaging criteria. We have performed similar multi-omics analysis in combination with patient-reported outcomes and quality-of-life measures. This is interesting because, when you add patient-reported outcomes to remission criteria, the remission rate goes down quite dramatically.

Roy Meys, University of Maastricht, the Netherlands, published a paper last year, which showed that patient-reported outcomes weren't strongly linked to lung function or the other measures we usually look at. Instead, they were associated with specific systemic pathways that made biological sense and could potentially be targeted with a dual-warhead antibody.

What kind of systemic pathways and antibodies?

TNF pathways and TNF-associated pathways are coming up, which makes sense if you think of symptoms like fatigue, which is one of the major issues that people with asthma have, even when they're treated well with biologics.

Q9 In terms of moving forwards, what do you think is the biggest unmet need in asthma management?

The biggest unmet need involves those who don't have classic T2-high biology. We have no drugs that have passed clinical trials because the mechanisms are more diverse and we don't have a biomarker to identify those mechanisms, so we just lump everyone in together.

Since we have no biomarkers at present, we can't differentiate between a patient who might respond to a drug and a patient who might not. Take anti-IL-17 therapies, for example. I think Th17 biology is important in certain subgroups of people with asthma, but because we don't have a biomarker, we just combine all patients together and the trial fails. Similarly, issues arise across many chronic inflammatory diseases where more personalised drug therapy is needed but biomarkers cannot, as yet, identify who to give a specific drug or biologic to. As such, we have to get away from the mindset that a single disease will provide our blockbuster drug. The drugs may have blockbuster potential when considered across several allergic or inflammatory diseases.

Q10 What is the take-home message you'd like to leave allergy and immunology specialists with?

The key message for allergy and immunology specialists is that we have really good state of the art immunology presented here at EAACI. This is not seen in respiratory meetings. I've just come back from the American Thoracic Society International Conference, where the science is good but lacks the hardcore immunology, and that's where we're going to make advances.

Bringing together great clinicians and great scientists will help make both better, but it will also help us make those changes in disease diagnosis and treatment. If you could bring engineers in, that would be fantastic, because they can help with biomarkers and a whole range of wearables.

Another thing is mobiles phones and watches, which can track and record our data. We're not good at keeping the data to ourselves or using it for academic research. We readily give it to companies via purchase agreements, who then sell this onto insurance agencies, for example. And I think this is something we, as a community, should be thinking about. Let's utilise that data by linking it to our electronic healthcare records and our personal databases.