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AI IN PREDICTING AND MANAGING ALLERGIC REACTIONS

PRADIP T. KHARAT[1], SHUBHAM G. DOIFODE[2], DR. SUNIL S. JAYBHAYE[3], KOMAL B. JAISWAL[4], YOGESH A. UKARDE[1]

1.Student of Bachelor in Pharmacy, Dr.Babasaheb Ambedkar Technological University, Raigad, Lonere.

2. Department of Pharmaceutics, Dr. Babasaheb Ambedkar Technological University, Raigad, Lonere.

3.Department of Pharmaceutical Analysis, Dr. Babasaheb Ambedkar Technological University, Raigad, Lonere.

4.Department of Pharmaceutical Chemistry, Dr. Babasaheb Ambedkar Technological University, Raigad, Lonere.

ABSTRACT

AI has been and still is used in many allergic reactions and studies, mainly to characterize disease endotypes and phenotypes and create models to forecast future disease outcomes. But the majority of implementations have relied on comparatively basic data from a single source, like surveys. Furthermore, reporting and methodological approaches are deficient. This review offers a useful, practical manual for carrying out AI-based research in allergies reactions. It includes an overview of common pitfalls and solutions, a blueprint for organizing analysis pipelines (from variable selection to result interpretation), and an introduction to fundamental AI concepts and techniques.AI has the potential to improve allergy surveillance by integrating environmental and population-level data, power digital twins, and facilitate augmented reality training.AI has been applied to the management, diagnosis, treatment, and prediction of allergic diseases in recent years. People's mental health and quality of life can be severely impacted by allergic diseases, which are a type of chronic non-communicable disease that can affect many different systems and organs. This paper examines the use of AI in asthma, atopic dermatitis, food allergies, allergic rhinitis, and urticaria from the standpoints of disease prediction, diagnosis, treatment, and management.

KEYWORDS: Artificial Intelligence, Allergic Disease, Machine Learning, Diagnosis And Prediction, Management

INTRODUCTION

AI is being used more and more in allergy and immunology to automate clinical documentation, analyze large-scale electronic health record (EHR) data, predict oral food challenge (OFC) outcomes, and customize immunotherapy protocols.[1-2]

Asthma, allergic rhinitis, food allergies, eczema, and drug allergies are among the allergic diseases that are becoming more common, according to the World Allergy Organization (WAO), especially in industrialized countries and urbanizing low- and middle-income countries.[3-4]

AI is still not widely used in clinical allergy care, though. Few tools have been successfully implemented in real-world settings, and the majority of published AI medical devices are proof-of-concept or retrospective validations.[5]

The purpose of this review is to serve as a reference and guide for AI-based pediatric allergy research. It is divided into three parts: an introduction to pertinent AI terms and concepts, methods, typical problems and solutions, and a guide for organizing and reporting AI-based research; a summary of studies using AI in pediatric allergy in novel and significant ways; and a discussion of the potential and constraints of AI in pediatric allergy. Allergy disorders in children are diverse and intricately linked.[6] Pediatric allergy research is an appropriate setting for AI-driven research when combined with the increased availability of large-scale (bio)medical data.[7-8]

The high frequency of allergies in children. AI that facilitates interactive text, image, and audio synthesis and generation.[9-10] AI is essential for speeding up drug discovery, automating and improving patient care .[11]

ARTIFICIAL INTELLIGENCE

Healthcare is one of the many industries that artificial intelligence (AI) is revolutionizing. AI is becoming more and more important in the treatment of chronic illnesses. AI-powered virtual health assistants have been shown to improve medication adherence among patients with chronic illnesses, according to a study published in The Lancet Digital Health .[12] Livongo's AI-driven strategy greatly enhanced glycemic control and decreased the frequency of diabetes-related complications, according to a study by Downing et al.[13] AI could predict adverse cardiovascular events by analyzing electronic health records, according to a recent study published in Nature. This would help customize preventive measures more successfully than conventional methods .[14]

AI has the potential to fundamentally change how we understand, diagnose, treat, and manage allergic diseases, including asthma.[15-16] AI has already shown promise in treating childhood allergies. AI was utilized in the Smith et al. study to diagnose asthma in 500 pediatric patients who had respiratory symptoms by analyzing data from electronic health records. The outcomes were contrasted with conventional diagnostic techniques. In diagnosing asthma, the AI tool outperformed conventional techniques with an accuracy of 92%, sensitivity of 89%, and specificity of 94%. which had 85% accuracy, 82% sensitivity, and 88% specificity.[17]

AI in the form of machine learning has proven to be more effective than conventional diagnostics for respiratory infections, allergic rhinitis, and persistent cough.[18-19] On the other hand, there are currently no studies on how well AI manages the progression of allergic diseases from pediatric to adult stages. One of the most significant challenges for individuals with allergies and asthma, as well as their families, is the transition. In order to support the transitional care of adolescents and young adults with allergic diseases and/or asthma, the European Academy of Allergy and Clinical Immunology (EAACI) has created evidence-based guidelines for medical professionals. Early transition initiation (11–13 years) is encouraged by these recommendations. medication simplification, patient education, an organized multidisciplinary approach, psychological assistance, as well as incorporating family and friends in self-management. [20]

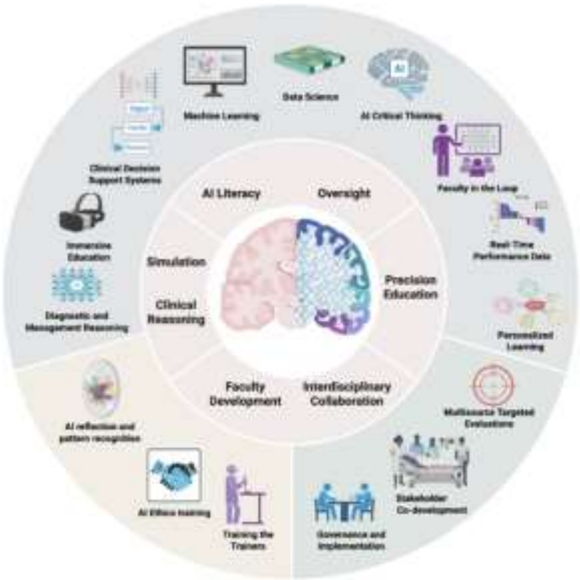

FIGURE NO. 1 MANAGEMENT OF AI

MACHINE LEARNING

ML is frequently categorized based on how it learns from data. In supervised learning, the model learns patterns linked to given labels with the goal of predicting labels in new data (e.g., unseen patients with specific symptoms having a disease or not). Classification (categorical labels, such as asthma subtypes) and regression (continuous labels, such as lung function results) are two categories of supervised learning. Instead of using labels in unsupervised learning, the model "independently" investigates unique patterns (subgroups) within data (such as eczema trajectories) onto which It offers recommendations for labels. Semi-supervised and active learning differ primarily in how they assign labels to unlabelled data, and they are helpful on large data sets where a small subset is labelled and labelling is challenging or time-consuming.

Deep learning, a subfield of machine learning, has become extremely popular in recent years due to its superior performance in analyzing unstructured data, including medical images.

In a similar vein, deep learning techniques have surpassed skilled medical professionals in identifying breast cancer from imaging data, with nine FDA-approved applications to date. [21]

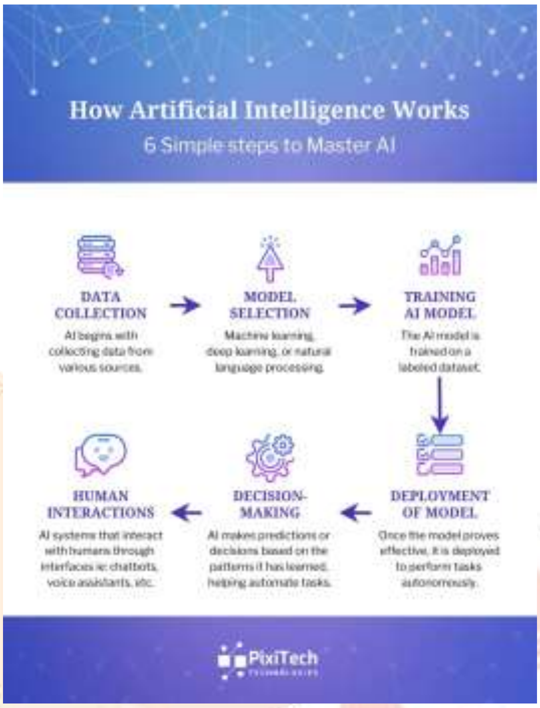

FIGURE NO. 2 MACHINE LEARNING

DIFFERENT ALLERGIC DISEASE

Hundreds of millions of people worldwide suffer from allergic diseases, such as atopic dermatitis (AD), food allergies, asthma, and allergic rhinitis (AR). Over the past few decades, there has been a steady increase in the prevalence of these conditions. Globally, 5.6 million children were diagnosed with AD in 2019, and an estimated 81 million children had asthma. Ten Additionally, according to data from the World Allergy Organization (WAO), allergen-specific immunoglobulin E (IgE) antibodies show that up to 40% of the world's population is sensitized to environmental allergens.[22] Due to increased morbidity and, in extreme situations, potentially fatal reactions like anaphylaxis, allergic diseases place a heavy burden on health care systems, economies, and personal quality of life. Conventional diagnostic and therapeutic approaches may not be able to provide accurate, individualized care due to the heterogeneity of allergic diseases and their underlying mechanisms. In fact, research indicates that patients may experience trial-and-error therapies that result in less than ideal disease management, higher medical costs, and a lower standard of living.[23] Researchers and clinicians are becoming more interested in cutting-edge technologies that can integrate multifactorial data to guide precise therapeutic decisions due to the growing recognition of the need for personalized approaches to allergy management. The shortcomings of the current paradigms for allergy diagnosis and treatment, in particular, call for new data-driven methods that can enhance disease identification, customize management plans, and more accurately forecast disease progression. Artificial intelligence (AI) has become a game-changing technology in contemporary medicine, providing promising solutions for clinical practice decision support, pattern recognition, and the analysis of complicated datasets. A variety of computational methods are covered by the AI, including Natural language processing, machine learning (ML), deep learning, and big data analytics have all shown outstanding achievements in diagnostic imaging, illness prediction, and treatment optimization in a number of medical specialties, including oncology, cardiology, and neurology.[24] In light of these developments, AI has enormous potential to transform allergy conventional management by filling in important gaps in Accurate diagnosis, risk assessment, and customized treatment but also by empowering patients.[25]

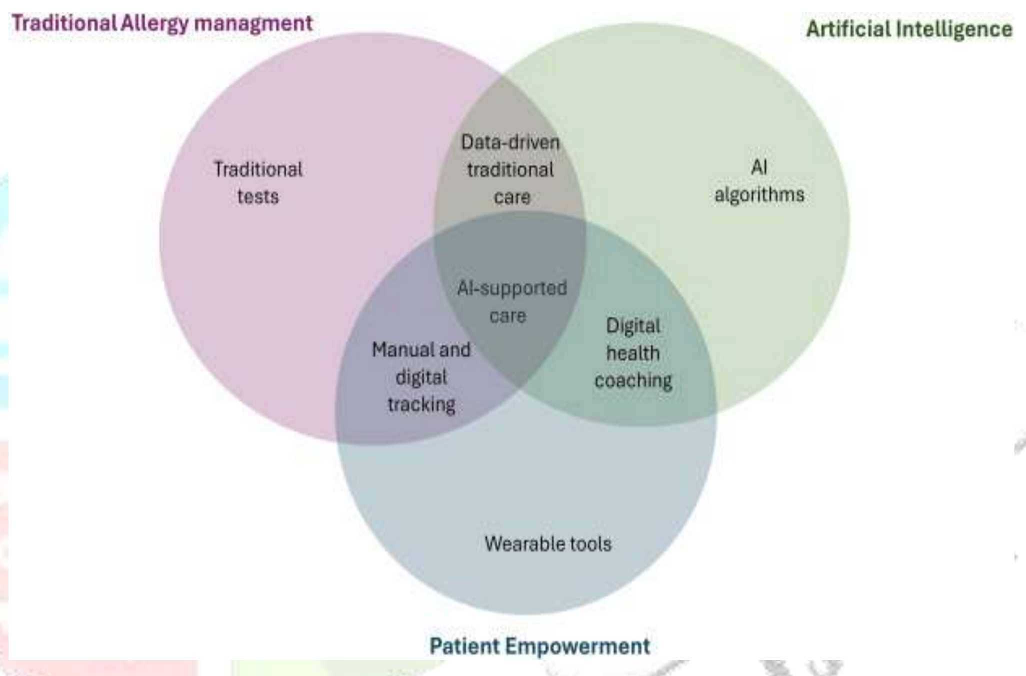

FIGURE NO. 3 TRADITIONAL ALLERGY AND MANEGMENT

1. Predicting Allergic Reaction Types

AI models (machine learning, deep learning) use large datasets—such as patient history, genetics, environmental data, and clinical records—to predict:

a) Type I Hypersensitivity (Immediate Allergic Reaction)

- Asthma
- Allergic rhinitis
- Food allergies
- Anaphylaxis

b) Type II Hypersensitivity

- AI helps detect drug-induced antibody reactions (e.g., hemolytic anemia).

c) Type III Hypersensitivity

- Predicts risks linked to immune-complex diseases (e.g., serum sickness).

d) Type IV Hypersensitivity (Delayed Reaction)

2. AI in Diagnosis of Allergies

AI improves diagnostic accuracy by combining:

a) Medical history analysis

- Prior reactions
- Exposure patterns
- Coexisting diseases

b) Lab data prediction

- AI interprets:
- IgE levels
- Skin prick tests
- Patch tests
- Eosinophil counts

c) Imaging-based detection

- Deep learning models detect:
- Atopic dermatitis severity from skin images
- Sinus inflammation in allergic rhinitis via CT scans

d) Electronic Health Record (EHR) mining

- AI flags high-risk allergic reactions to medications in hospitals.

3. AI in Understanding Causes of Allergies

AI helps identify causes by analyzing:

a) Environmental factors

- Pollution
- Pollen count
- Weather changes
- Humidity levels

b) Genetic factors

- AI analyzes genomic data to find:
- Inherited allergy risks
- Immune response patterns

c) Lifestyle & dietary correlations

- AI detects patterns that humans may miss, such as:
- Foods linked to cross-reactive allergies
- Sleep, stress, and allergy intensity

AI IN ALLERGY PREDICTION & MANAGEMENT

Patient Data Input

(History, Symptoms, Lab Tests, Images, Wearables, Environment)

↓

AI Data Processing

(Machine Learning + Deep Learning)

↓

Prediction of Allergy Type

(Type I, II, III, IV; Severity)

↓

Symptom & Risk Assessment

(Skin changes, breathing patterns, vitals, environment exposure)

↓

Diagnosis Support

(Interpret IgE, skin tests, lab results, imaging, EHR alerts)

↓

Treatment Planning

(Medication, immunotherapy, dose adjustment, biologics)

↓

Continuous Monitoring System

(Wearables, smart inhalers, apps, air-quality + diet tracking)

↓

Real-Time Alerts & Feedback

(Symptom worsening, anaphylaxis, reminders, AI advice)

↓

Improved Allergy Management

(Early detection, personalized care, reduced complications)

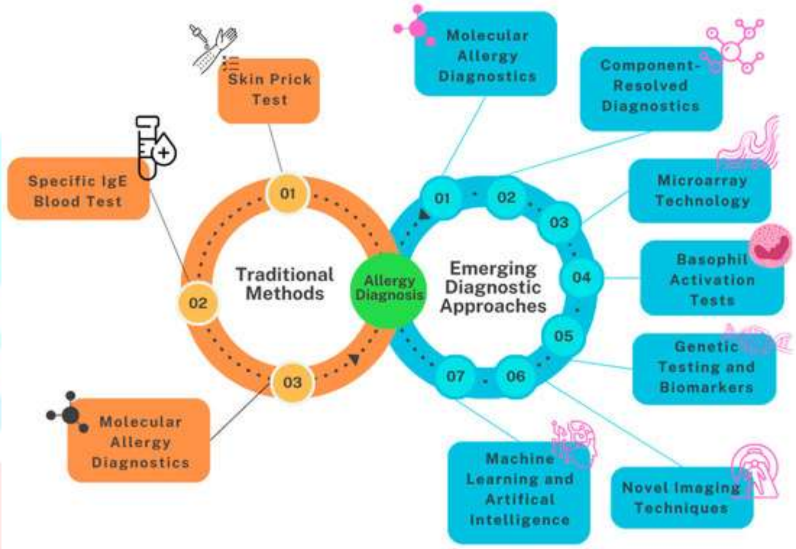

FIGURE NO. 4 DIAGNOSIS AND TRADITIONAL METHOD OF ALLERGY

CHALLENGES AND ETHICAL CONSIDERATIONS

In order to maintain the safety, equity, and integrity of our patients' ongoing high-quality care, integrating AI into healthcare presents a number of difficulties that must be taken into account.

1. Bias In Data

The AI outputs are only as unbiased as their training data. Medical datasets are riddled with our own biases, societal biases and individual provider biases, that often reflect historic disparities and structural inequities in health care. Underrepresented populations may have less robust data given decreased access to health care, which can impact algorithmic performance. In addition, inherent biases can be further amplified when used by an algorithm, one well-described case was from Obermeyer and associates.[26]

2. Hallucination And Accuracy Concerns

Even though AI occasionally produces outputs that seem accurate but are actually inaccurate due to hallucinations, these occurrences are generally declining as AI develops. However, one cannot accept AI without question, so one of the main goals of more recent tools is to comprehend how a model comes to its conclusions. In one study, ChatGPT answered 91% of common allergy myths with accuracy or somewhat accuracy.[27]

For other conditions like eosinophilic esophagitis, GPT-based chatbots were often inaccurate. Physicians' ability to verify sources within medical records is enhanced when evidence is directly linked to the output. Nonetheless, a lot of systems continue to be "black boxes," with little knowledge of how decisions are made. Applications in the healthcare industry require AI that provides a clear explanation of the factors taken into account, the conclusions drawn, and the recommendations' uncertainties.

3. The Physician Impact

Physician practice patterns and cognitive processes are significantly impacted by the use of AI. It has been demonstrated that automation bias, in which doctors over-rely on and accept AI recommendations, happens even when AI provides "contradictory and clinically nonsensical information." More subtly, when routine cognitive tasks are delegated to AI systems, this could lead to "de-skilling." The effect of AI assistance on gastrointestinal colonoscopy performance and adenoma detection rates was investigated in a recent preprint study.[28]

4. Resource Consumption

AI's effects on the environment should be taken into account. Large language models require a lot of energy to train, and the Data centers need a lot of cooling, which means they use a lot of water. In certain descriptions, a single sending a ChatGPT email while sipping a bottle of water; and The water cost of training ChatGPT-3 was equal to that of producing 100 pounds of beef.

5. Health Economics And Access

AI-powered allergy tools offer substantial potential for lowering costs, improving operational effectiveness, and increasing access to care. According to cost-effectiveness analyses, daily hospital expenses could be reduced by more than $21,000 at first and up to $290,000 in ten years.

6. Ethical And Legal Considerations

A major legal dilemma arises when AI systems provide inaccurate information and cause harm to a patient. The question of whether developers, implementing organizations, or the clinicians using these tools are liable is not sufficiently addressed by current frameworks. The AMIA highlights that the companies creating, implementing, and maintaining the AI system should bear the responsibility.[29]

- Limited data quality
- Risk of algorithm bias
- Privacy issues with personal health data
- Need for clinical validation

LIMITATIONS

AI has a lot of potential to help with the transition of allergy care from childhood to adulthood, but there are a few drawbacks that need to be taken into account. First, the quality and completeness of the data used to train AI systems have a significant impact on their accuracy and efficacy. Inaccurate forecasts and recommendations may result from incomplete or biased data, endangering patient safety. The quality and variety of the datasets used to train algorithms are critical to the efficacy of AI in healthcare. To prevent biased or incorrect predictions, high-quality, diverse datasets are essential. Disparities in healthcare outcomes can result from bias in AI caused by non-representative data that excludes different demographic groups. An AI system that was primarily trained on data from a particular ethnic group, for example, might not function well for people from other backgrounds. According to a recent study, biased datasets can result in notable differences in healthcare outcomes and delivery. In order to develop more equitable AI applications in healthcare that offer precise predictions and treatment recommendations for all patient groups, it is important to ensure data diversity and quality. The use of AI in healthcare also raises important privacy and ethical concerns. To safeguard patient data, healthcare providers must make sure AI applications adhere to strict regulatory requirements.

FIGURE NO. 5 LIMITATION AND CHALLENGES

APPLICATION

1. Allergy Prediction

- Predict a person's risk of developing allergies.
- Identify triggers like food, pollen, dust, or medication.
- Use genetic and lifestyle data to detect allergy patterns early.

2. Early Detection of Severe Allergic Reactions By Using

- Heart rate
- Breathing rate
- Skin changes
- Wearable devices or smartwatches. (These systems can alert the patient or doctor before the reaction becomes severe.)

3. Personalized Allergy Treatment

- Individual immune responses
- Allergy history
- Environmental factors

4. AI-Powered Diagnostic Tools

- AI can analyze blood tests (IgE levels), skin test images, or breath samples.
- It helps identify the exact allergen faster and more accurately.
- Reduces misdiagnosis.

5. Smart Inhalers & Smart EpiPens (Devices using AI can)

- Track when and how often a patient uses them.
- Detect incorrect technique.
- Warn about worsening conditions.
- Suggest immediate actions during allergic attacks.

6. Environmental Allergy Alerts

- Predict high-risk days.
- Send notifications to allergy patients.
- Suggest preventive actions (mask, medication, staying indoors).

7. AI in Food Allergy Detection

- Scan food labels for hidden allergens.
- Identify allergen-containing ingredients using image recognition.
- Suggest safe food alternatives.

8. AI in Immunotherapy Monitoring

- Monitor symptoms daily.
- Adjust dose levels.
- Predict treatment success.

9. Real-Time Emergency Alert Systems

- Alert family members or doctors.
- Call emergency services.
- Suggest steps to manage the reaction until help arrives.

10. AI in Drug Allergy Detection

- Predict possible allergic reactions.
- Compare genetic data to known drug-allergy profiles.
- Reduce risk of severe side effects

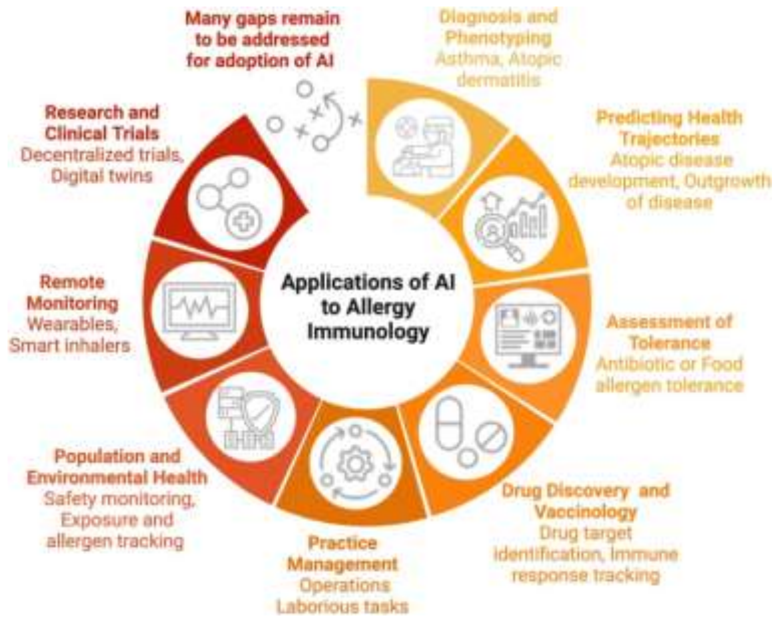

FIGURE NO. 6 APPLICATIONS

FUTURE PROSPECTIVES

- **Explainable AI (XAI):**

  Tools like SHAP and LIME will improve patient understanding and clinician trust by providing succinct, understandable explanations of AI decisions.

- **Federated Learning:**

  Enables multi-center model training without sharing raw patient data, facilitating safe collaboration and supporting customized digital twins.

- **Multi-Omics Integration:**

  Combining genomic, proteomic, metabolomic, and environmental data will enhance allergy risk prediction and personalize treatment regimens.

- **AR/VR Technologies:**

  Immersion simulations will improve training for scenarios such as handling anaphylaxis and complex immunotherapy procedures.

- **Population-Level Surveillance:**

  AI analysis of environmental data, including pollen and pollution, will help predict seasonal allergy spikes and spot trends in sensitization.

- **Overall:**

  These advancements will lead to more proactive, customized, and predictive (precision) medicine in the treatment of allergies.

CONCLUSIONS

AI is reshaping clinical allergy practice, from diagnostics and documentation to personalised treatment and public health surveillance. Despite ongoing technical, ethical, and operational challenges, the potential for transformative impact is clear. Realising this potential will require multidisciplinary collaboration, robust governance, continuous evaluation, and inclusive design. With thoughtful implementation, the allergy community stands on the brink of a digital revolution that could redefine how allergic diseases are understood, treated, and prevented.

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