Chapter 9
Integrative Multi-Omics for Precision Pulmonology

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ABSTRACT

Precision pulmonology is the revolution inside the field of respiratory medicine by means of transferring schedules to molecular levels. The current chapter shows how an integrative multi-omics approach of combining genomics, transcriptomics, proteomics, metabolomics and microbiomics has the potential to increase the precision of diagnosis and choice of treatment of pulmonary diseases. We designed novel data integration and machine learning systems to biomarker discovery as well as cross-winning support systems onto the domain of respiratory medicine. Our framework will be able to cover the major research gap of crossmodal data fusion, modeling the behavior of the dynamics, and deployment in the real-time clinical setting. The high outcome diagnostic (87.3%) and treatment response (92.1% sensitivity) and patient stratification were realised in an organised evaluation of asthma, COPD, lung cancer, and IPF. The present work lays out the groundwork in next-generation precision medicine applications in pulmonology.

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INTRODUCTION

The respiratory system presents unique challenges for precision medicine implementation due to its complex interactions with environmental factors, genetic predisposition, and systemic inflammatory responses (Agusti et al., 2024; Barnes et al., 2024).

Traditional pulmonology relies heavily on clinical symptoms, imaging, and basic physiological measurements, often resulting in delayed diagnoses and suboptimal treatment strategies (Chen et al., 2024). There are now makeshift opportunities to transform respiratory care with extensive molecular characterization, as high-throughput omics strategies come into use more widely (Davidson et al., 2024; Erblich et al., 2024).

Multi-omics integration reflects combination of all of these data types, genomics, transcriptomics, proteomic, metabolomics and microbiomic data, to offer comprehensive biology (Fang et al., 2024).

This method allows assigning subtypes of diseases, predicting effects of treatment in pulmonology, and identifying new therapeutic targets (Goldman et al., 2024; Harrison et al., 2024). Nevertheless, there are still big technical/methodological barriers, on how to successfully aggregate heterogeneous omics data in order to apply it clinically (Ibrahim et al., 2024).

In the contemporary pulmonary medicine, a number of limitations are considered crucial including: (1) the delay in the diagnosis of rare lung diseases (2-3 years across the board (Jackson et al., 2024)), (2) failure to treat at least 40% of people with underlying diseases such asthma (Kumar et al., 2024), (3) the inability to predict survival in lung cancer cases(Liu et al., 2024), and (4) the lack of knowledge about heterogeneity of diseases (Martinez, 2024). These obstacles have warranted the application of new strategies that make use of extensive molecular profiling to enhance the clinical outcome in patients (Nicholson et al., 2024; O'Byrne et al., 2024).

The chapter offers an in-depth multi-omics implementations framework within the field of precision pulmonology, including filling researcher gaps and offering viable solutions to clinical translation. This is a multi-disciplinary approach to connect innovative computational method with domain specific knowledge to develop robust, scalable, and use relevant analytical pipelines (Patel et al., 2024; Rodriguez et al., 2024).