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Virtual patient with temporal evolution for mechanical ventilation trial studies: A stochastic model approach

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Abstract

Background and objective: Healthcare datasets are plagued by issues of data scarcity and class imbalance. Clinically validated virtual patient (VP) models can provide accurate in-silico representations of real patients and thus a means for synthetic data generation in hospital critical care settings. This research presents a realistic, time-varying mechanically ventilated respiratory failure VP profile synthesised using a stochastic model. Methods: A stochastic model was developed using respiratory elastance (E_{rs}) data from two clinical cohorts and averaged over 30-minute time intervals. The stochastic model was used to generate future E_{rs} data based on current E_{rs} values with added normally distributed random noise. Self-validation of the VPs was performed via Monte Carlo simulation and retrospective E_{rs} profile fitting. A stochastic VP cohort of temporal E_{rs} evolution was synthesised and then compared to an independent retrospective patient cohort data in a virtual trial

across several measured patient responses, where similarity of profiles validates the realism of stochastic model generated VP profiles. Results: A total of 120,000 3-hour VPs for pressure control (PC) and volume control (VC) ventilation modes are generated using stochastic simulation. Optimisation of the stochastic simulation process yields an ideal noise percentage of 5–10% and simulation iteration of 200,000 iterations, allowing the simulation of a realistic and diverse set of E_{rs} profiles. Results of self-validation show the retrospective E_{rs} profiles were able to be recreated accurately with a mean squared error of only 0.099 [0.009–0.790]% for the PC cohort and 0.051 [0.030–0.126]% for the VC cohort. A virtual trial demonstrates the ability of the stochastic VP cohort to capture E_{rs} trends within and beyond the retrospective patient cohort providing cohort-level validation. Conclusion: VPs capable of temporal evolution demonstrate feasibility for use in designing, developing, and optimising bedside MV guidance protocols through in-silico simulation and validation. Overall, the temporal VPs developed using stochastic simulation alleviate the need for lengthy, resource intensive, high cost clinical trials, while facilitating statistically robust virtual trials, ultimately leading to improved patient care and outcomes in mechanical ventilation.

Author keywords

Clinical time series data; Mechanical ventilation; Respiratory elastance; Stochastic model; Temporal evolution; Virtual patient

Indexed keywords

Device tradenames

SciVal Topics

Metrics

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