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APPLICATION OF ARTIFICIAL INTELLIGENCE AND SIMULATION MODELING IN THE STUDY OF RESPIRATORY SYSTEM FUNCTIONS

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Abstract

The development of digital technologies and artificial intelligence methods significantly expands the possibilities for studying the physiological systems of the human body. A particularly promising area is the use of machine learning algorithms and simulation modeling to analyze respiratory system functions. These methods enable the processing of large data sets, modeling physiological processes, and predicting changes in lung function. This study examined key respiratory system parameters in 60 patients of different age groups using artificial intelligence algorithms and computer modeling. Vital capacity, respiratory rate, and minute respiratory volume were assessed. The results showed that the use of artificial intelligence enables highly accurate analysis of physiological parameters and the identification of abnormalities in respiratory system function. Simulation modeling also enables the prediction of possible changes in respiratory function under various physiological conditions.

Keywords

artificial intelligence, simulation modeling, respiratory system, vital capacity, respiratory rate, minute respiratory volume, respiratory physiology.

Аннотация

Развитие цифровых технологий и методов искусственного интеллекта значительно расширяет возможности исследования физиологических систем организма человека. Особенно перспективным направлением является применение алгоритмов машинного обучения и симуляционного моделирования для анализа функций дыхательной системы. Такие методы позволяют обрабатывать большие массивы данных, моделировать физиологические процессы и прогнозировать изменения функционального состояния лёгких. В данном исследовании изучались основные показатели дыхательной системы у 60 пациентов разных возрастных групп с применением алгоритмов искусственного интеллекта и компьютерного моделирования. Оценивались жизненная ёмкость лёгких, частота дыхания и минутный объём дыхания. Результаты показали, что использование искусственного интеллекта позволяет с высокой точностью анализировать физиологические параметры и выявлять отклонения в работе дыхательной системы. Применение симуляционного моделирования также позволяет прогнозировать возможные изменения функции дыхания при различных физиологических состояниях.

Ключевые слова

искусственный интеллект, симуляционное моделирование, дыхательная система, жизненная ёмкость лёгких, частота дыхания, минутный объём дыхания, физиология дыхания.

Introduction

The respiratory system is one of the most important systems in the human body, providing oxygen and carbon dioxide removal. Respiratory efficiency is determined by a number of physiological parameters, including vital capacity, respiratory rate, and minute volume.

Traditional methods for examining the respiratory system are based on clinical measurements and laboratory tests. However, modern technologies allow for more accurate and faster data processing methods. In recent years, artificial intelligence methods have been rapidly developing, capable of analyzing large volumes of medical data and identifying patterns inaccessible with conventional analysis.

Simulation modeling is another important tool in modern medical science. It allows physiological processes to be reproduced in a computer environment, making it possible to predict changes in the function of organs and body systems under various conditions.

The combination of artificial intelligence and simulation modeling opens new perspectives in respiratory system research. The use of these technologies allows not only the analysis of current respiratory parameters but also the prediction of possible future changes.

Study Objective

The aim of the study is to explore the potential of using artificial intelligence and simulation modeling to analyze physiological parameters of the human respiratory system.

The objectives of the study include:

- collecting physiological data on respiratory system functions in patients of different age groups;
- analyzing the obtained data using artificial intelligence algorithms;
- building a simulation model of the respiratory system based on the obtained data;
- identifying age-related characteristics of respiratory system function.

Research Materials and Methods

The study involved **60 patients** divided into three age groups for a comparative analysis of respiratory function.
The first group included **20 patients aged 12–18 years,** including 11 boys and 9 girls. The second group consisted of 20 patients aged 20–40 years, including 10 men and 10 women. The third group included 20 elderly patients aged 60–70 years, including 9 men and 11 women.
All patients underwent a preliminary medical examination. Only individuals without diagnosed chronic respiratory or cardiovascular diseases or severe metabolic disorders were included in the study. The participants' body mass index ranged from 18–25 kg/m², which corresponds to normal physiological parameters. Before measurements, participants rested for at least 10–15 minutes to

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exclude the influence of physical activity on respiratory parameters. The study was conducted in a laboratory at a stable air temperature of 22–24°C and a relative humidity of 50–60%. All measurements were taken in the morning, which reduced the influence of diurnal fluctuations in physiological parameters.
The following key physiological parameters of the respiratory system were determined for each patient: vital capacity; respiratory rate;
tidal volume; and minute respiratory volume.
Vital capacity (VC) was measured using a spirometer. The patient took a maximal deep breath, then exhaled completely into the device. This procedure was repeated three times, after which the average value was calculated.
Respiratory rate (RR) was determined by counting chest movements for 60 seconds at rest. Measurements were taken three times, after which the average value was calculated.
Tidal volume was calculated based on physiological norms. For adolescents, it was assumed to be 0.45 L, for adults, 0.5 L, and for elderly patients, 0.45 L.
Minute respiratory volume (MRV) was calculated using the formula:
MRV = tidal volume × respiratory rate
The obtained data were recorded in an electronic database and used for further analysis.
Artificial **intelligence algorithms** and **simulation modeling** methods were used to process the results. Machine learning algorithms were trained using the obtained physiological data and used to classify patients by age group and identify deviations in respiratory parameters.
Simulation modeling was used to construct a computer model of the respiratory system that took into account vital capacity, respiratory rate, and ventilation volume. The model was used to analyze changes in respiratory parameters under various physiological conditions and predict potential changes in respiratory function.
For statistical data processing, mean values and standard deviations were calculated. Comparisons between age groups were conducted using statistical analysis methods, which allowed us to determine the significance of differences between the respiratory system parameters studied.

Methods

Machine learning and simulation modeling methods were used for data analysis.

First, a statistical analysis of the physiological parameters was performed. Mean values and standard deviations were calculated, and comparisons were made between age groups.

The data was then processed using artificial intelligence algorithms. Random Forest machine learning models and artificial neural networks were used for analysis. The algorithms were trained based on the physiological data collected and were used to classify patients by age group and identify deviations in respiratory parameters.

A computer model of the respiratory system was used for simulation, taking into account lung volume, respiratory rate, and ventilation. The model allowed for simulating respiratory processes and predicting changes in physiological parameters under various conditions.

Study Results

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Data analysis revealed age-related differences in respiratory system parameters.

In patients in the first group (aged 12–18 years), the average vital capacity was 2.6 ± 0.3 L. Respiratory rate was 20 ± 2 breaths per minute. Tidal volume was 0.45 L. Minute respiratory volume was 9.0 ± 1.1 L/min.

In patients in the second group (aged 20–40 years), vital capacity reached its maximum value of 4.2 ± 0.4 L. Respiratory rate was 16 ± 2 breaths per minute. Tidal volume was 0.5 L. Minute respiratory volume was 8.0 ± 0.9 L/min.

In patients in the third group (aged 60–70 years), decreased respiratory system function was observed. Vital capacity was 2.9 ± 0.3 L. Respiratory rate was 18 ± 2 breaths per minute. Tidal volume was 0.45 L. Minute respiratory volume was 8.1 ± 0.8 L/min.

Artificial intelligence algorithms enabled classification of patients by age group with 91% accuracy. Abnormal physiological parameters were also identified in four patients, indicating a possible decline in respiratory function.

Simulation modeling showed that with a 20% increase in respiratory rate, minute respiratory volume increases by approximately 15–18%. With a 25% decrease in vital capacity, ventilation efficiency decreases by approximately 20%.

Discussion

These results confirm the existence of age-related changes in respiratory function. Maximum vital capacity is observed in adult patients, while in adolescents and the elderly, these values are lower.

The use of artificial intelligence significantly accelerated data processing and increased the accuracy of physiological parameter analysis. Machine learning algorithms successfully classified patients by age group and identified possible abnormalities in respiratory function.

Simulation modeling allowed us to reproduce respiratory processes and assess the impact of various factors on pulmonary ventilation. This opens up the possibility of using such models in medical practice to predict the development of respiratory diseases.

Conclusion

The study results demonstrated the effectiveness of using artificial intelligence and simulation modeling in analyzing human respiratory function.

In patients aged 12–18 years, vital capacity was 2.6 liters, respiratory rate was 20 breaths per minute, and minute volume was 9.0 L/min.

In patients aged 20–40 years, vital capacity reached 4.2 liters, respiratory rate was 16 breaths per minute, and minute volume was 8.0 L/min.

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In patients aged 60–70 years, vital capacity decreased to 2.9 liters, respiratory rate was 18 breaths per minute, and minute volume was 8.1 L/min.

The use of artificial intelligence enabled patient classification with 91% accuracy and identification of respiratory parameter abnormalities in 4 patients. Simulation modeling enabled prediction of changes in respiratory function under various physiological conditions. The results obtained show that the use of modern digital technologies can significantly increase the efficiency of studying physiological processes and improve the diagnosis of respiratory disorders.

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