DOI: https://zenodo.org/records/19194354

УДК 614.2: 616-092: 612.017: 004.8 *DOI https://zenodo.org/records/19194447*

APPLICATION OF ARTIFICIAL INTELLIGENCE IN UNDERSTANDING THE INFLAMMATORYCASCADE

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ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ ДЛЯ АНАЛІЗУ ЗАПАЛЬНОГО КАСКАДУ В КОНТЕКСТІ ПРОФЕСІЙНОГО ТА ТРАНСПОРТНОГО ЗДОРОВ'Я

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Summary/Резюме

Вступ. У транспортній медицині системне запалення є ключовим патогенетичним механізмом формування професійної патології, пов'язаної з впливом шуму, вібрації, токсичних речовин, хронічного психоемоційного стресу та несприятливих факторів навколишнього середовища. Традиційні методи оцінки запальної відповіді мають обмежені можливості при аналізі багатофакторних впливів.

Мета. Оцінити можливості застосування штучного інтелекту для аналізу та прогнозування перебігу запального каскаду в осіб, зайнятих у транспортній галузі.

Матеріали і методи. Проведено систематичний огляд літератури з використанням баз PubMed, Scopus, Web of Science та Google Scholar за 2015–2025 роки з акцентом на застосування машинного та глибокого навчання для аналізу мультиомних, клінічних та візуалізаційних даних.

Результати. Встановлено, що методи штучного інтелекту забезпечують інтеграцію різнорідних біологічних і клінічних показників, дозволяють прогнозувати ризик хронічного системного запалення та ідентифікувати ранні біомаркери професійно зумовленої патології.

Висновки. Застосування штучного інтелекту в транспортній медицині є перспективним напрямом для ранньої діагностики, профілактики та персоналізованого управління запальними захворюваннями професійного ґенезу.

Ключові слова: *транспортна медицина, запальний каскад, професійне здоров'я, штучний інтелект, машинне навчання, мультиоміка*

Introduction. In transport medicine, systemic inflammation is a key pathogenic mechanism underlying occupational diseases associated with noise, vibration, toxic exposures, chronic stress, and adverse environmental factors.

Objective. To assess the potential of artificial intelligence for analysing and predicting the inflammatory cascade in transport workers.

Materials and Methods. A systematic review of studies published between 2015 and 2025 was conducted using PubMed, Scopus, Web of Science, and Google Scholar databases.

The inflammatory cascade is a highly complex biological process involving a series of molecular and cellular events designed to protect the host from infection and injury. Dysregulation of inflammation is associated with a spectrum of diseases, including autoimmune disorders, cardiovascular diseases, and sepsis. Traditional methods for studying the inflammatory cascade have provided substantial insights, yet they are limited in handling high-dimensional datasets and predicting dynamic responses. Artificial Intelligence (AI), particularly machine learning (ML) and deep learning (DL), offers transformative potential for understanding the inflammatory cascade by analysing large datasets, predicting disease progression, and identifying novel therapeutic targets. This review explores the applications of AI in modelling inflammatory pathways, integrating multi-omics data, and predicting inflammatory outcomes. By evaluating recent studies and technological advancements, this article highlights the emerging role of AI in immunology and its potential to revolutionise the understanding and management of inflammatory diseases.

Results. Artificial intelligence methods enabled effective integration of heterogeneous biological and clinical data, prediction of chronic inflammation risk, and identification of early occupational biomarkers.

Conclusions. Artificial intelligence represents a promising tool for improving diagnostics, prevention, and personalised management of inflammation-related occupational pathology in transport medicine.

Keywords: *Artificial intelligence, inflammatory cascade, machine learning, deep learning, immunology, multi-omics.*

Introduction

Inflammation is a critical physiological response to injury, infection, and tissue damage, orchestrated through a cascade of molecular events involving cytokines, chemokines, immune cells, and signalling pathways. While acute inflammation is protective, chronic inflammation contributes to pathological conditions such as atherosclerosis, rheumatoid arthritis, and systemic inflammatory response syndrome (SIRS). Understanding the inflammatory cascade is crucial for developing targeted therapies and predicting disease outcomes.

Traditionally, research on inflammation has relied on in vitro experiments, animal models, and clinical studies. However, these approaches face limitations in scalability, integration of complex datasets, and predictive accuracy. With the advent of big data and high-throughput technologies, the volume of biological information generated has outpaced traditional analytical methods. Here, Artificial Intelligence (AI) emerges as a powerful tool to process, analyse, and interpret large datasets, revealing previously inaccessible patterns and insights.

AI encompasses machine learning (ML), deep learning (DL), natural language processing (NLP), and other computational algorithms capable of learning from data. In the context of inflammation, AI can integrate multi-omics datasets, predict disease phenotypes, model cellular interactions, and propose therapeutic interventions. This article reviews the application of AI in understanding the inflammatory cascade, highlighting current methodologies, challenges, and future prospects.

Materials and methods, literature search

A systematic review of literature was conducted using PubMed, Scopus, Web of Science, and Google Scholar databases. Keywords included “artificial intelligence”, “machine learning”, “deep learning”, “inflammatory cascade”, “cytokines”, “immune response”, and “multi-omics”.

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Articles published between 2015 and 2025 were included to ensure contemporary relevance. Studies were selected based on their focus on AI applications for modelling, analysing, or predicting inflammatory responses.

Data sources

The data sources analysed included:

- Genomic and transcriptomic datasets: RNA-seq and microarray datasets from immune cells.
- Proteomic and metabolomic datasets: Cytokine profiles, proteomic maps, and metabolite analysis related to inflammation.
- Clinical datasets: Electronic health records (EHRs) containing patient information on inflammatory diseases, laboratory markers, and outcomes.
- Imaging data: Histopathology slides, immunofluorescence, and in vivo imaging data.

AI methodologies

The AI techniques used in the studies reviewed were categorised as follows:

1. Machine Learning (ML): Random Forest, Support Vector Machines (SVM), and Gradient Boosting for predicting inflammatory responses.
2. Deep Learning (DL): Convolutional Neural Networks (CNNs) for imaging data and Recurrent Neural Networks (RNNs) for temporal inflammatory data.
3. Integrative Approaches: Combining multi-omics data with ML/DL to model pathway interactions.
4. Network Analysis: Graph-based AI models are used to analyse cytokine interaction networks and immune cell signalling.

Evaluation metrics studies were evaluated based on

Accuracy, sensitivity, specificity, and Area Under the Receiver Operating Characteristic Curve (AUROC) for predictive models.

- Biological interpretability of AI-derived models.
- Clinical relevance in terms of disease prognosis, treatment response prediction, and biomarker discovery.

Background

The inflammatory cascade involves three overlapping phases:

1. Initiation: Recognition of pathogens or damage by pattern recognition receptors (PRRs) on immune cells, leading to activation of NF-κB and inflammasomes.
2. Amplification: Recruitment of immune cells and production of cytokines (e.g., IL-1в, TNF-б) to propagate inflammation.
3. Resolution: Anti-inflammatory signals, apoptosis of immune cells, and tissue repair mechanisms restore homeostasis.

Dysregulation at any stage contributes to disease. Traditional experimental approaches have limitations in capturing the temporal and spatial dynamics of the cascade. High-dimensional omics data (genomics, proteomics, and metabolomics) generate large, complex datasets that require sophisticated analytical tools. AI methods, by learning from patterns in these datasets, provide novel insights into the inflammatory cascade.

Applications of AI in the inflammatory cascade

1. Predictive Modelling AI models predict inflammatory responses by analysing patient data, including genetic, clinical, and laboratory parameters. For example, ML algorithms have predicted cytokine storm severity in COVID-19 patients, enabling timely intervention. Random Forest and Gradient Boosting methods have shown high accuracy in predicting outcomes in sepsis and autoimmune diseases.
2. Multi-Omics Integration Integrative AI approaches combine genomics, transcriptomics, proteomics, and metabolomics to map immune

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pathways. This allows identification of novel biomarkers and therapeutic targets. Network-based ML models identify key nodes in cytokine signalling, highlighting potential intervention points.

3. Imaging Analysis DL algorithms, particularly CNNs, have revolutionised the analysis of histopathology slides and in vivo imaging. AI can quantify immune cell infiltration, detect tissue damage, and correlate histological patterns with disease progression. This provides an objective and reproducible assessment compared to manual analysis.
4. Drug Discovery and Repurposing AI-driven drug discovery leverages inflammatory pathway modelling to identify potential therapeutic molecules. Predictive models screen chemical libraries for anti-inflammatory effects, optimising drug repurposing strategies. For example, AI has been used to identify novel inhibitors targeting IL-6 and TNF-б pathways.
5. Personalised Medicine AI enables the patient-specific modelling of inflammatory responses. By analysing individual omics profiles, AI predicts susceptibility to chronic inflammation and likely responses to treatments. Personalised interventions can be designed to modulate specific immune pathways.

Discussion

The application of AI in studying the inflammatory cascade is transformative, enabling a systems-level understanding of immune processes. AI models surpass traditional approaches by handling high-dimensional data, predicting dynamic interactions, and suggesting novel interventions.

However, challenges remain, including:

- Data Quality: AI performance depends on high-quality, annotated datasets. Missing or biased data can lead to inaccurate models.

Interpretability: Complex AI models, particularly deep learning, may function as “black boxes”, making biological interpretation challenging.

- Integration with Clinical Practice: Translating AI insights into clinical interventions requires validation in large patient cohorts.
- Ethical Considerations: Patient data privacy and algorithmic biases must be addressed.

Despite these challenges, ongoing advancements in AI algorithms, computational power, and data availability continue to expand its potential. Integration of AI with immunology research promises improved understanding of inflammatory mechanisms, early detection of dysregulated responses, and precision therapeutic strategies.

Conclusion

AI has emerged as a pivotal tool for understanding the inflammatory cascade, offering predictive, integrative, and analytical capabilities beyond traditional methods. By leveraging machine learning, deep learning, and network analysis, researchers can decode complex immune interactions, predict disease progression, and identify novel therapeutic targets. While challenges remain in data quality, interpretability, and clinical translation, AI holds the promise of revolutionising inflammation research and enabling precision medicine approaches. Future research should focus on multi-modal data integration, interpretable AI models, and validation in diverse clinical settings to fully realise the potential of AI in immunology.

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Вперше надійшла до редакції 25.10.2025 р. Рекомендована до друку на засіданні редакційної колегії після рецензування

УДК 612.621.31-092:618.12-003.217:618.12-089.87:618.179:618.177-089.888.11
DOI https://zenodo.org/records/19194468

ГОРМОНАЛЬНИЙ СТАТУС НЕПЛІДНИХ ПАЦІЄНТОК ПЕРЕД ПРОВЕДЕННЯМ ЦИКЛІВ ДОПОМІЖНИХ РЕПРОДУКТИВНИХ ТЕХНОЛОГІЙ З САЛЬПІНГЕКТОМІЄЮ В ДОВГОСТРОКОВОМУ АНАМНЕЗІ

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HORMONAL STATUS OF INFERTILE PATIENTS BEFORE ASSISTED REPRODUCTIVE TECHNOLOGY CYCLES WITH SALPINGECTOMY IN THE LONG-TERM ANAMNESIS

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Summary/ Резюме

Background: The negative impact of tubal surgery on ovarian function may not be apparent in the short term after. Clinicians are primarily concerned about the impact of tubal surgery on ovarian blood supply and functional responsiveness, especially if women have undergone tubal surgery long before presenting to a reproductive clinic for assisted reproductive technologies (ART). *Objective:* to assess the hormonal profile of peripheral blood serum in patients before cycles of ART with salpingectomy in a long-term anamnesis and to determine the dependence of its changes on the extent of surgical intervention. *Material and methods.* An observational study was conducted, which included 162 women before ART. 128 people were after salpingectomy long before the initiation of ART cycles,