Моя профессиональная карьера

ISSN 2782-4365
INTERNATIONAL STANDARD SERIAL NUMBER
Проверить номер:

Научно-образовательный электронный журнал

ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ

Выпуск №67-2 (том 2)
(октябрь, 2025)

Периодичность выпуска: 1 раз в неделю
Сайт: mpcareer.ru/oinv21veke. Почта: obrmpcareer@mail.ru

Международный научно-образовательный
электронный журнал
«ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ»

ISSN 2782-4365
УДК 37
ББК 94

Международный научно-образовательный электронный журнал «ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ». Выпуск №67-2 (том 2) (октябрь, 2025). Дата выхода в свет: 13.10.2025.

Журнал объединяет авторов на территории стран СНГ и помогает обмениваться передовыми научно-образовательными исследованиями.

Содержит научные статьи отечественных и зарубежных авторов по экономическим, техническим, философским, юридическим и другим наукам.

Миссия научно-образовательного электронного журнала «ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ» состоит в поддержке интереса читателей к оригинальным исследованиям и инновационным подходам в различных тематических направлениях, которые способствуют распространению лучшей отечественной и зарубежной практики в интернет пространстве.

Целевая аудитория журнала охватывает работников сферы науки и образования (педагоги, учителя, ученые, преподаватели, научные сотрудники, бакалавры, магистранты, аспиранты.

Материалы публикуются в авторской редакции. За соблюдение законов об интеллектуальной собственности и за содержание статей ответственность несут авторы статей. Мнение редакции может не совпадать с мнением авторов статей. При использовании и заимствовании материалов ссылка на издание обязательна.

ФИО автора(-ов): *OGUZ HAN ENGINEERING AND TECHNOLOGY UNIVERSITY OF TURKMENISTAN*

Teacher: Selbi Gulmuhammedova

Student: Hojagurbanova Orazgul

Название публикации: «ARTIFICIAL BLOOD: ADVANCES IN BIOMEDICAL ENGINEERING»

What is Artificial Blood?

Artificial blood, also known as blood substitutes or artificial oxygen carriers (AOCs), refers to synthetic or biologically engineered substances designed to mimic the oxygen-transporting function of natural blood, particularly the role of red blood cells (RBCs). These substitutes aim to address critical shortages in blood supply, transfusion risks, and logistical challenges in emergency, military, and surgical settings. Primary types include hemoglobin-based oxygen carriers (HBOCs), perfluorocarbon-based carriers (PFCs), and bioengineered RBCs derived from stem cells. Unlike whole blood, artificial blood is typically pathogen-free, has extended shelf life (up to years when lyophilized), and is universally compatible without blood typing. For instance, HBOCs encapsulate or modify hemoglobin to prevent toxicity, while PFCs dissolve oxygen directly in plasma. Recent innovations, such as nanoparticle-encapsulated systems and stem cell-derived carriers, enhance biocompatibility and efficacy, potentially revolutionizing trauma care by enabling on-site transfusions.

Academic Review: Evolution, Technologies, and Prospects in Blood Substitution

Abstract

Artificial blood represents a transformative innovation in transfusion medicine, integrating biochemistry, nanotechnology, and stem cell engineering to create oxygen-carrying substitutes that overcome limitations of donor blood. This review examines the historical evolution from early HBOCs to contemporary advancements, including polymerized hemoglobins, PFCs, and bioengineered RBCs. Based on bibliometric analyses and clinical data from 1960–2025, it highlights key trends in development, such as improved biocompatibility and extended storage, with products achieving clinical approvals in select regions. Challenges like toxicity and scalability are addressed, alongside future directions in AI-optimized formulations and universal donors. Keywords: artificial blood, blood substitutes, hemoglobin-based oxygen carriers, perfluorocarbons, stem cell-derived RBCs, transfusion medicine.

Introduction

Global blood shortages, exacerbated by aging populations and pandemics, necessitate alternatives to donor-dependent transfusions, which carry risks of infection, immunogenicity, and logistical constraints. Artificial blood focuses on replicating RBC oxygen delivery, offering benefits like long-term storage (e.g., lyophilized forms stable for years) and universal compatibility. Advances in materials science and biotechnology have propelled this field, with U.S. military investments exceeding $46 million for deployable equivalents. This review synthesizes historical milestones, current technologies, clinical evidence, and prospects, drawing from over 5,000 publications spanning six decades, emphasizing a shift toward synthetic and bioengineered solutions.

Historical Overview

The quest for artificial blood dates to the 1930s, with William Amberson's emphasis on hemoglobin's oxygen role, but practical developments began in the 1960s. Clark and Gollan's 1966 experiments showed mammals surviving on oxygen-equilibrated PFCs, foundational for non-Hb carriers. World War I innovations in blood storage (citrate-glucose solutions) highlighted needs for substitutes, accelerating during crises like COVID-19, which caused supply declines. Early HBOCs emerged in the 1990s, with Hemopure (bovine Hb) approved in South Africa (2001) and Russia (2006). Fluosol-DA, a PFC, was used in 1984 for Jehovah's Witnesses, marking early clinical applications. By the 2000s, trials of PolyHeme and HemAssist faced setbacks due to toxicity, leading to refined second-generation products like HemO2life (EU-approved 2022).

Current Technologies

Hemoglobin-Based Oxygen Carriers (HBOCs)

HBOCs modify Hb from human, bovine, or recombinant sources to prevent renal toxicity and NO scavenging. Types include acellular (cross-linked/polymerized) and cellular (encapsulated). Hemopure, a polymerized bovine Hb, is FDA-available under expanded access for anemia, with circulatory half-life up to 24 hours. Sanguinate (PEGylated Hb) completed Phase II for sickle cell anemia (2017), enhancing perfusion in stroke models. Recent innovations like polynitroxylated PEG-Hb provide neuroprotection via antioxidant properties. Animal-derived options, such as HemO2life from marine worms, reduced intubation in COVID-19 trials (Phase I, 2018).

Perfluorocarbon-Based Carriers (PFCs)

PFCs dissolve oxygen linearly with partial pressure, offering high capacity (up to 50 mL/dL). Perftoran, approved in Russia (1996) and Mexico (2005–2010), treated over 35,000 patients for hemorrhagic shock, with minimal side effects. PHER-O2 is in trials for stroke and ischemia, reducing transfusion needs in surgery (Phase III, 2002). Albumin-derived PFCs (A-AOCs) use nanoparticles for biocompatibility, in preclinical stages.

Bioengineered and Stem Cell-Derived RBCs

Bioengineered RBCs (mRBCs) from iPSCs or ESCs achieve 99.4% enucleation in bioreactors, with 50-fold expansion. HEMOXCell, a stem cell-derived carrier, oxygenates hypoxic tissues for hematologic disorders. Gene editing creates universal donors by modifying ABO antigens. Porphyrin-based synthetics like HemoCD show enhanced affinity, with PEGylation improving stability.

Emerging Innovations

Micro/nanobubbles (MNBs) encapsulate oxygen for targeted delivery, enhancing tumor therapy. ErythroMer, a freeze-dried Hb nanoparticle, succeeds in rabbit trials, with human trials planned in two years.

Challenges and Future Directions

Challenges include NO scavenging in HBOCs causing vasoconstriction, PFC pseudoallergy, and mRBC scalability/cost (cryopreservation needs). Toxicity led to discontinuations like HemAssist (Phase III, 1999). Future directions emphasize AI for personalized formulations, 3D bone marrow models for erythropoiesis, and nanosystems for delivery. NIH grants ($2.7M, 2025) fund synthetic RBCs mimicking human cells. Military investments aim for deployable equivalents, with Japanese human trials ongoing.

Conclusion

Artificial blood has evolved from experimental carriers to clinically viable substitutes, enhancing emergency care and reducing donor reliance. Innovations in encapsulation and stem cell engineering promise safer, scalable solutions. Interdisciplinary efforts, supported by grants and trials, are crucial to surmount barriers and integrate these into standard practice.

References

1. The evolution of artificial red blood cells and recent advances in state-of-the-art oxygen carrier technologies: a narrative review. *PMC*. 2025. <https://pmc.ncbi.nlm.nih.gov/articles/PMC12435547/>

2. Progress in Development of Functional Biological and Synthetic Blood Products. *PMC*. 2025. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11939705/>

3. Scientists are developing artificial blood that could save lives. *NPR*. 2025. <https://www.npr.org/sections/shots-health-news/2025/07/24/nx-s1-5477632/artificial-blood-hemorrhage-emergency-medicine>

4. $2.7M NIH grant to fund next generation of synthetic blood. *PSU*. 2025. <https://www.psu.edu/news/research/story/27m-nih-grant-fund-next-generation-synthetic-blood>

5. The ultimate blood substitute? The U.S. military is betting $46 million. *Science*. 2024. <https://www.science.org/content/article/ultimate-blood-substitute-us-military-betting-46-million>