



*VII international scientific conference
Brussels. Belgium
30.06-01.07.2026*

DIALOGUE OF TIMES: PAST, PRESENT, FUTURE

*Proceedings of the VII International
Scientific and Practical Conference*

30 June – 1 July 2026

BRUSSELS. BELGIUM

2026

UDC 001.1

BBC 1

VII International Scientific and Practical Conference «Dialogue of times: past, present, future», June 30 – July 1, 2026, Brussels. Belgium. 116 p.

ISBN 978-91-65424-79-1

DOI <https://doi.org/10.5281/zenodo.21226354>

Publisher: «SC. Scientific conferences»

Main organization: **artmedia²⁴**

Editor: Hans Muller

Layout: Ellen Schwimmer

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The sample of the citation for publication is Gugin Aleksandr, Lisnievska Yuliia ANTI-ADVERTISING IN THE HOTEL BUSINESS // VII International Scientific and Practical Conference «Dialogue of times: past, present, future», June 30 – July 1, 2026, Brussels. Belgium. Pp.9-11, URL: <https://sconferences.com>

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Biological sciences

TAXONOMIC COMPOSITION OF MUSCIDAE SPECIES BY SUBFAMILIES IN SAMARKAND REGION

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Zoophilic flies belonging to the family Muscidae represent one of the most important groups of Diptera associated with livestock farms and veterinary-sanitary conditions. Many species are known as mechanical vectors of pathogenic microorganisms and parasites, causing economic losses in animal husbandry. In addition, Muscidae species play an important role in decomposition processes and nutrient cycling within ecosystems.

The family Muscidae is one of the largest families of Diptera and includes numerous synanthropic and zoophilic species distributed worldwide. Several studies have investigated the taxonomy, ecology, and biology of Muscidae species in Central Asia and neighboring regions. However, information regarding the current taxonomic structure of Muscidae flies in the Samarkand region remains limited.

Therefore, the aim of the present study was to determine the subfamily-level taxonomic composition of Muscidae species distributed in the Samarkand region and to assess their relative abundance.

The study was conducted in various natural and anthropogenic biotopes of the Samarkand region. Specimens were collected from livestock farms, pastures, residential areas, and sites rich in organic substrates using entomological nets, sticky traps, and bait traps.

Collected samples were examined in laboratory conditions under a binocular microscope. Identification was carried out using standard taxonomic keys and diagnostic characteristics.

The identification of Diptera families was based on the key developed by E.P. Narchuk. Species determination and classification were performed using the works of A.A. Stackelberg, G.Ya. Bey-Bienko, and other authoritative entomological references, including the monograph *Flies and Disease*.

The obtained data were analyzed statistically, and the proportion of each subfamily was calculated as a percentage of the total number of species identified.

The analysis of Muscidae species identified in the Samarkand region revealed the presence of four subfamilies. Significant differences were observed in their relative abundance (Figure 1).

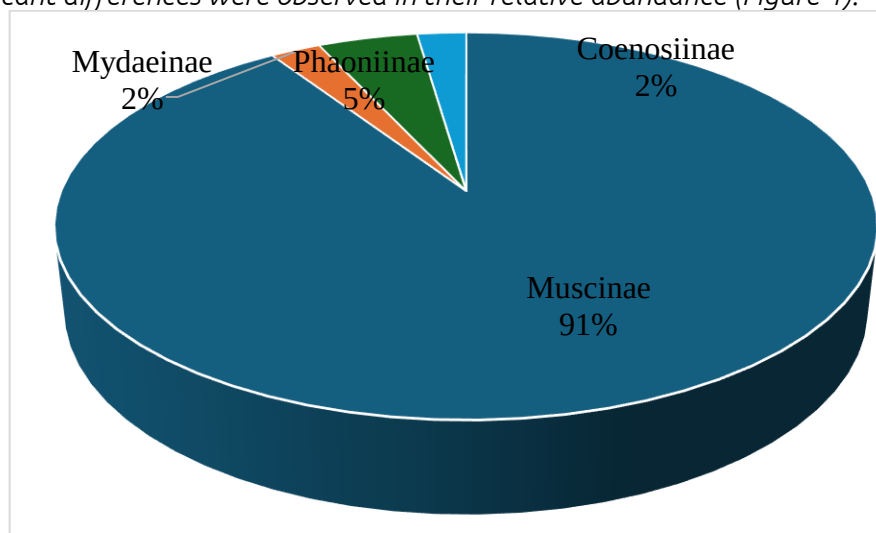


Figure 1. Distribution of Muscidae species by subfamilies in Samarkand region (%)

Muscinae was the dominant group, comprising 91% of the total species recorded. This dominance indicates the high ecological adaptability and broad distribution of Muscinae representatives in the environmental conditions of the Samarkand region.

The second most abundant group was Phaoniinae, accounting for 5% of the identified species. Although less numerous than Muscinae, representatives of this subfamily constitute an important component of the regional entomofauna.

Coenosiinae and Mydaeinae each represented 2% of the total fauna. Their relatively low occurrence may be associated with specific ecological requirements and habitat preferences.

The predominance of Muscinae can be explained by the ecological plasticity of its representatives, their ability to exploit a wide range of breeding substrates, and their close association with livestock environments. Similar patterns have been reported in other regions of Central Asia and the Palearctic zone.

These results demonstrate that Muscinae is the leading ecological group within the family Muscidae in the Samarkand region and plays a significant role in shaping the zoophilic fly fauna.

Conclusion. The study revealed that the family Muscidae in the Samarkand region is represented by four subfamilies. Muscinae was identified as the dominant group, accounting for 91% of the total species composition. Phaoniinae represented 5%, while Coenosiinae and Mydaeinae each accounted for 2%.

The dominance of Muscinae is associated with its high ecological adaptability and close relationship with livestock-associated habitats. The obtained results contribute to the understanding of the biodiversity and taxonomic structure of Muscidae flies in the Samarkand region and may serve as a scientific basis for future veterinary-entomological monitoring and control programs.

References

1. Zimin J.I.S. Key to the larvae of synanthropic flies of Tajikistan (for stage III). - Moscow: Nauka, 1948. p.-114.
2. Lobanov A.M. Morphology, systematics, and ecology of flies of the family Muscidae (Diptera, Caliptrata): Abstract of a Doctor of Biological Sciences Dissertation. - Leningrad, 1976. -48 p.
3. Narchuk E.P. Key to the families of dipterous insects of the fauna of Russia and adjacent countries. St. Petersburg: Zoological Institute of the Russian Academy of Sciences. 2003-p. 66-143.
4. Ragimkhanova F.K., Aliev Sh.K. Seasonal dynamics of activity and abundance of zoophilic flies in the foothill and mountain belts of Dagestan // Russian Parasitological Journal. - Makhachkala, 2009. - No. 3. pp.-77-81.
5. Ruzimurodov A.R. Biological parasitism. Optimization of animal husbandry/- Samarkand, 2010. - "Zarafshon". B.-157

Cultural sciences

INTERCULTURAL MENTORING IN THE PROFESSIONAL DEVELOPMENT OF FOREIGN LANGUAGE TEACHERS

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Abstract

This study investigates the role of intercultural mentoring in the professional development of foreign language teachers working in higher education contexts. As globalisation intensifies cross-cultural encounters in academic and professional settings, the demand for teachers who possess not only linguistic but also intercultural communicative competence (ICC) has grown substantially. Despite this, existing mentoring frameworks in many post-Soviet educational systems remain monocultural in orientation, prioritising subject-matter knowledge transfer over intercultural awareness. Drawing on survey data collected from 84 EFL teachers and 12 mentors at Uzbek higher education institutions, the study identifies key structural gaps in current mentoring practice and evaluates the impact of an intercultural mentoring intervention on participants' self-reported ICC development. Results indicate that structured intercultural mentoring significantly enhances teachers' cultural flexibility, reflective capacity, and intercultural pedagogical confidence. The paper concludes with a framework for embedding intercultural mentoring into formal teacher professional development programmes.

Keywords: *intercultural mentoring, professional development, foreign language teachers, intercultural communicative competence, teacher education, reflective practice, EFL*

1. INTRODUCTION

The internationalization of higher education has fundamentally redefined the professional competencies expected of foreign language teachers. It is no longer sufficient for an EFL or EFL-adjacent instructor to demonstrate mastery of grammatical rules and pedagogical techniques; today's language educator is expected to function as a cultural mediator, a reflective practitioner, and a bridge-builder between linguistically and culturally diverse communities (Byram, 2021; Kramsch, 2009). This expanded role demands purposeful, sustained professional development — development that is itself intercultural in design and delivery.

Mentoring has long been recognized as one of the most effective vehicles for teacher professional growth (Hobson et al., 2009; Ingersoll & Strong, 2011). Yet the dominant model of mentoring in many educational systems — including those of Central Asia — remains largely transmissive: an experienced practitioner transfers pedagogical knowledge and institutional norms to a novice, reproducing established practices rather than interrogating them. When the professional landscape demands intercultural competence, such monocultural mentoring becomes structurally inadequate.

Intercultural mentoring reorients the mentoring relationship around the development of cultural flexibility, critical self-reflection on one's own cultural assumptions, and the capacity to navigate culturally complex classroom and institutional contexts (Zachary, 2011; Mezirow, 2000). This paper examines the theoretical foundations of intercultural mentoring, analyses current gaps in mentoring provision for EFL teachers in Uzbekistan, and reports findings from an intervention study designed to test whether structured intercultural mentoring produces measurable gains in teachers' intercultural communicative competence.

The research is guided by three questions: (1) What are the structural features of existing mentoring programmes for EFL teachers in Uzbek higher education, and to what extent do they address intercultural dimensions of professional practice? (2) Does participation in structured intercultural mentoring produce self-reported gains in teachers' ICC? (3) What design principles should inform an intercultural mentoring framework adapted to the post-Soviet Central Asian educational context?

2. LITERATURE REVIEW

2.1. Intercultural communicative competence and teacher professional development

Byram's (1997, 2021) model of intercultural communicative competence remains the most widely cited theoretical foundation for intercultural pedagogy. The model identifies five interconnected

dimensions — attitudes, knowledge, skills of interpreting and relating, skills of discovery and interaction, and critical cultural awareness — and argues that competence in all five is required for effective cross-cultural communication. Deardorff (2006) extended this framework by emphasizing the processual nature of ICC: competence is not a fixed endpoint but a continuously evolving capability, shaped by reflective engagement with diverse cultural encounters.

Teacher professional development research has increasingly emphasized the importance of transformative learning — the kind of deep cognitive and affective shift that occurs when practitioners are invited to examine the assumptions underlying their own cultural worldview (Mezirow, 2000; Viète & Mayer, 2020). Johnson and Golombek (2011) demonstrated that narrative-based mentoring, in which teachers construct and interrogate accounts of their own practice, produces more durable professional change than skills-transmission models. These findings converge with intercultural learning theory in suggesting that reflection on cultural experience — rather than the acquisition of cultural facts — is the primary mechanism of ICC development.

2.2. Mentoring models and their intercultural dimensions

Traditional mentoring in teacher education has typically been conceptualised as a dyadic, hierarchical relationship in which a senior practitioner guides a junior colleague through the norms of the profession (Hobson et al., 2009). While effective for socialising novices into established practice, this model is ill-suited to the development of intercultural competence, which requires the mentor themselves to model cultural humility, openness to multiple perspectives, and comfort with ambiguity (Bennett, 2015; Zachary, 2011).

Several alternative models have emerged in recent decades. Peer mentoring distributes authority more equally and creates space for collaborative inquiry into shared intercultural challenges (Parker et al., 2008). Group mentoring, or mentoring circles, enables teachers to pool diverse cultural experiences and generate richer interpretive frameworks than any dyadic pairing can produce (Mullen, 2012). Cross-cultural mentoring — in which mentor and mentee are deliberately matched across cultural boundaries — has been shown to produce particularly significant gains in cultural flexibility and perspective-taking, though it also introduces relational risks that require careful facilitation (Ensher & Murphy, 2011).

2.3. Intercultural mentoring in Central Asian and post-Soviet contexts

Empirical research on mentoring for EFL teachers in post-Soviet Central Asia remains sparse. Studies by Smagulova (2008) and Dzhakysbekov (2019) document the persistence of transmissive, subject-focused mentoring norms in Kazakhstani and Uzbek higher education respectively, attributing this persistence partly to Soviet-era pedagogical traditions that privileged content expertise over reflective or intercultural dimensions of teaching. Karimov and Yusupova (2020) found that Uzbek EFL teachers reported feeling underprepared to navigate culturally complex classroom interactions, and that existing professional development provision offered little structured support for the development of intercultural awareness. These findings point to a significant opportunity for intercultural mentoring as a targeted professional development intervention.

3. METHODS

3.1. Research design

This study employed a mixed-methods design combining a pre-post survey with qualitative interviews to evaluate the impact of an intercultural mentoring intervention. The intervention ran over one academic semester (18 weeks) and was conducted at two higher education institutions in the Namangan region of Uzbekistan. Ethical approval was obtained from the institutional review board, and all participants provided written informed consent.

3.2. Participants

A total of 84 EFL teachers (61 female, 23 male; mean age 34.2 years; mean teaching experience 8.7 years) participated in the main survey study. Of these, 42 were assigned to the intercultural mentoring intervention group and 42 to a control group receiving standard continuing professional development provision. Twelve experienced teachers with prior international professional experience served as intercultural mentors. Purposive sampling was used to ensure a range of experience levels, departmental contexts, and prior exposure to intercultural professional development across both groups.

3.3. Intervention design

The intercultural mentoring intervention was designed around four structural components drawn from the literature: (a) structured dyadic mentor-mentee meetings (bi-weekly, 60 minutes); (b) facilitated group mentoring circles (monthly, 90 minutes); (c) a guided reflective journal protocol adapted from Johnson and Golombek's (2011) narrative inquiry framework; and (d) a cultural critical incident analysis task, completed individually and then discussed in the mentoring circle. Mentors received a two-day

preparatory workshop covering the theoretical foundations of ICC, facilitation techniques for intercultural dialogue, and strategies for managing discomfort during cross-cultural reflection.

3.4. Instruments

ICC development was measured using an adapted version of the Intercultural Development Inventory (IDI; Hammer et al., 2003), supplemented by a 28-item researcher-designed questionnaire assessing intercultural pedagogical confidence, cultural flexibility, and reflective practice orientation. Cronbach's alpha coefficients for the three subscales were 0.81, 0.79, and 0.84 respectively, indicating acceptable internal reliability. Post-intervention qualitative interviews ($n=24$, drawn equally from intervention and control groups) were analysed using thematic analysis following Braun and Clarke's (2006) framework.

3.5. Data analysis

Quantitative data were analysed using paired-samples *t*-tests to assess within-group change and independent-samples *t*-tests to assess between-group differences at the post-intervention measurement point. Effect sizes were calculated using Cohen's *d*. Qualitative data were coded inductively in the first cycle, then subjected to pattern coding in the second cycle to identify overarching themes across participants.

4. RESULTS

4.1. Quantitative findings

Pre-test scores on the ICC composite measure did not differ significantly between the intervention group ($M = 52.4$, $SD = 8.1$) and the control group ($M = 51.9$, $SD = 7.8$), $t(82) = 0.29$, $p = .77$, confirming baseline equivalence. At post-test, the intervention group showed a statistically significant increase ($M = 71.3$, $SD = 9.2$), while the control group showed only a modest non-significant change ($M = 54.6$, $SD = 8.3$). The between-group difference at post-test was significant, $t(82) = 9.41$, $p < .001$, with a large effect size ($d = 2.03$).

Subscale analysis revealed that the largest gains in the intervention group occurred on the cultural flexibility subscale (pre: $M = 16.2$; post: $M = 24.8$; $d = 1.94$) and the reflective practice orientation subscale (pre: $M = 17.1$; post: $M = 25.6$; $d = 2.11$). Gains on the intercultural pedagogical confidence subscale, while significant, were somewhat smaller (pre: $M = 19.1$; post: $M = 20.9$; $d = 0.68$), suggesting that a single semester of mentoring is sufficient to generate attitudinal and reflective shifts but may require longer engagement to translate into confident classroom application.

4.2. Qualitative findings

Thematic analysis of interview data yielded three principal themes. The first, cultural self-encounter, captured participants' reports of being prompted — for the first time in their professional lives — to examine their own cultural assumptions about teaching, learning, and teacher-student relationships. One participant described the experience as 'like being given a mirror I had never been offered before.' The second theme, relational safety as a precondition for intercultural risk, highlighted the importance of trust in the mentoring relationship: teachers reported being willing to expose cultural uncertainty and vulnerability only in mentoring relationships characterised by genuine mutual respect and non-evaluative dialogue.

The third theme, transfer friction, captured a tension noted by 18 of 24 interviewees between their newly developed intercultural awareness and the institutional constraints they encountered when attempting to apply it. Teachers described pressure to conform to established curricula, assessment formats, and pedagogical norms that left little room for culturally responsive teaching. This finding suggests that individual-level ICC development, while necessary, is insufficient without parallel institutional change.

5. DISCUSSION

The quantitative results of this study provide strong evidence that structured intercultural mentoring produces significant gains in EFL teachers' ICC, particularly in the dimensions of cultural flexibility and reflective practice. These findings are consistent with Deardorff's (2006) processual model of ICC development and with Johnson and Golombek's (2011) argument that reflective, narrative-based professional development produces deeper and more durable change than transmission-focused alternatives.

The qualitative theme of cultural self-encounter aligns closely with Mezirow's (2000) concept of transformative learning: the disorienting dilemma — the moment at which a practitioner confronts the inadequacy of their existing interpretive framework — appears to be a necessary precursor to genuine intercultural growth. The intercultural mentoring relationship, by creating structured opportunities for this kind of self-encounter within a supportive relational context, appears to function as a reliable mechanism for initiating transformative learning.

The transfer friction theme raises important questions about the relationship between individual development and institutional culture. Bennett (2015) and Kramsch (2009) have both argued that ICC cannot flourish in institutional environments that are structurally resistant to cultural diversity. The findings of this study suggest that intercultural mentoring programmes, to realise their full potential, must be embedded within broader institutional change processes — including curriculum reform, assessment redesign, and the development of an institutional culture that explicitly values intercultural competence as a professional and pedagogical goal.

This study has several limitations that should be noted. The sample was drawn from a single regional context, limiting the generalisability of findings to other post-Soviet or Central Asian settings. The intervention's duration of one semester may be insufficient to produce changes in classroom behaviour, as the subscale data suggest. Future research should employ longer intervention periods, incorporate classroom observation data, and include institutional-level variables as moderators of individual ICC development.

6. CONCLUSION

This study demonstrates that intercultural mentoring, when structured around reflective practice, critical cultural incident analysis, and genuine relational safety, can function as an effective mechanism for developing EFL teachers' intercultural communicative competence. The findings highlight the need to move beyond transmissive mentoring models toward frameworks that position cultural self-examination and perspective-taking as core professional activities. At the same time, the transfer friction findings underscore the importance of institutional-level support for teachers who are developing intercultural competence: individual growth that encounters structural resistance at the classroom and institutional level will not produce the pedagogical transformation that learners require.

For practitioners and programme designers, the study suggests a set of design principles for intercultural mentoring: the deliberate cultivation of relational safety; the use of structured reflective protocols; the incorporation of cross-cultural mentoring dyads; the provision of mentor preparatory training; and the embedding of mentoring within broader institutional commitments to intercultural education. These principles offer a starting point for the development of culturally responsive professional development frameworks that are adapted to the specific historical and institutional contexts of post-Soviet higher education.

References

1. Bennett, J. M. (2015). *The SAGE encyclopedia of intercultural competence*. SAGE Publications.
2. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
3. Byram, M. (1997). *Teaching and assessing intercultural communicative competence*. Multilingual Matters.
4. Byram, M. (2021). *Teaching and assessing intercultural communicative competence: Revisited*. Multilingual Matters.
5. Deardorff, D. K. (2006). Identification and assessment of intercultural competence as a student outcome of internationalization. *Journal of Studies in International Education*, 10(3), 241–266.
6. Dzhaksybekov, A. (2019). Mentoring practices in Uzbek higher education: A critical review. *Central Asian Journal of Education*, 4(1), 12–29.
7. Ensher, E. A., & Murphy, S. E. (2011). The mentoring relationship challenges scale: The impact of mentoring stage, type, and gender. *Journal of Vocational Behavior*, 79(1), 253–266.
8. Hammer, M. R., Bennett, M. J., & Wiseman, R. (2003). Measuring intercultural sensitivity: The Intercultural Development Inventory. *International Journal of Intercultural Relations*, 27(4), 421–443.
9. Hobson, A. J., Ashby, P., Malderez, A., & Tomlinson, P. D. (2009). Mentoring beginning teachers: What we know and what we don't. *Teaching and Teacher Education*, 25(1), 207–216.
10. Ingersoll, R., & Strong, M. (2011). The impact of induction and mentoring programs for beginning teachers: A critical review of the research. *Review of Educational Research*, 81(2), 201–233.
11. Johnson, K. E., & Golombek, P. R. (2011). *Research on second language teacher education: A sociocultural perspective on professional development*. Routledge.
12. Karimov, B., & Yusupova, D. (2020). EFL teacher preparation and intercultural competence in Uzbekistan. *Uzbek Journal of Educational Research*, 7(2), 44–61.
13. Kramsch, C. (2009). *The multilingual subject*. Oxford University Press.
14. Mezirow, J. (2000). *Learning as transformation: Critical perspectives on a theory in progress*. Jossey-Bass.

15. Mullen, C. A. (2012). *Mentoring: An overview*. In S. Fletcher & C. A. Mullen (Eds.), *The SAGE handbook of mentoring and coaching in education* (pp. 7–23). SAGE.
16. Parker, P., Hall, D. T., & Kram, K. E. (2008). *Peer coaching: A relational process for accelerating career learning*. *Academy of Management Learning & Education*, 7(4), 487–503.
17. Smagulova, J. (2008). *Language policies of kazakhization and their influence on language attitudes and use*. *International Journal of Bilingual Education and Bilingualism*, 11(3–4), 440–475.
18. Viète, R., & Mayer, D. (2020). *Practising intercultural learning in teacher education*. *Teaching Education*, 31(1), 30–44.
19. Zachary, L. J. (2011). *The mentor's guide: Facilitating effective learning relationships* (2nd ed.). Jossey-Bass.

Economic sciences

THE GLOBAL OIL MARKET AND AZERBAIJAN'S STRATEGY IN THE ENERGY RESOURCES MARKETS IN THE NEW CONDITIONS

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Abstract

The global oil market is undergoing a profound transformation. Driven by both long-term trends and recent exogenous shocks such as the global coronavirus pandemic and the geopolitical crises surrounding Ukraine and Iran, global oil demand, global oil production, and trade in crude oil and refined products are being transformed in real time. The main driver of this oil market restructuring is the approaching risk of peak global oil demand.

On the supply side, the US is strengthening its position in global oil production, driven by technological breakthroughs in shale oil production methods. Short-term oil supply elasticity has increased significantly. Sluggish global oil demand, coupled with expanding opportunities to rapidly increase oil production, has significantly reduced the risk of an oil supply shortage, at least in the medium term. This is forcing OPEC countries, desperately needing to maximize oil export revenues to maintain acceptable economic growth rates, to limit oil production at the expense of their market niche.

The parallel existence of these two segments in global oil trade has led to increased competition among oil exporters. A return to normalcy could present a new shock to the oil market. The US desire to maintain global economic dominance and control the growth of developing countries has turned the global energy market, particularly the oil market, into an arena of geopolitical confrontation. The study found that, under these new conditions, a key element of Azerbaijan's energy strategy has been the reorientation of oil exports to markets that compensate for the loss of customers. A combination of market diversification, a flexible tax policy, and strengthened partnerships with regional states has ensured Azerbaijan's resilience in this new environment. However, the risks of further fragmentation of global energy markets must be considered. This heightens the need to take measures to minimize these risks, including the development of alternative financial mechanisms that reduce dependence on the dollar system.

Keywords: global energy, oil, sanctions, cooperation, strategy, Iran, Russia, China, India, Europe, USA.

Introduction

The global oil market is currently undergoing profound transformation, driven not only by long-term trends within the oil industry itself but also by major exogenous shocks—the global coronavirus pandemic and the geopolitical crises surrounding Iran and Ukraine. On the demand side, the growing risk of peaking global oil consumption by the end of the decade is paramount. On the supply side, the main drivers of this transformation are rising oil production in the US, driven by technological breakthroughs that have made extracting hard-to-recover oil profitable, as well as Western sanctions against the Russian oil and gas sector, which have triggered a process of reshaping global oil export and import flows.

The US desire to maintain global economic dominance and control the growth of developing countries has turned the global energy market, and the oil market in particular, into an arena of geopolitical confrontation.

Discussion

The global oil market: scale and structure

Oil has played a significant role in the global energy balance for over 100 years. Its share of global energy production and consumption increased from 3% at the turn of the 19th and 20th centuries to almost 45% in the 1980s. While global oil consumption in 1900 was only about 16 million tons, it increased more than 2.5 times in the 10 years to 1910, reaching 44 million tons. Further increases in industrial production and the use of automobiles and other internal combustion engine-powered equipment meant that from 1910 to 1980, global oil consumption doubled on average every 12 years, according to the International Energy Agency (IEA). By 1980, global oil consumption had grown to 3 billion tons. According to OPEC data, global liquid hydrocarbon consumption (LHC) increased 4.9-fold from 1960 to 2024, reaching 103.8 million barrels per day. Although oil's share of the global energy balance declined to 34%, it retained its leadership in the structure of global energy production.

Two fundamental characteristics of the modern oil market should be noted. First, while before the oil crises of the 1970s, the rate of growth in global oil consumption was determined primarily by developed countries, the situation has since changed significantly. In countries outside the Organization for Economic Cooperation and Development, LHC consumption increased 11.2-fold from 1960 to 2024, while in OECD countries it increased only 2.8-fold. In terms of volume, the largest growth during this period was observed in Asia-Pacific countries – by 37.3 million barrels per day (consumption reached 39.1 million barrels per day). The main contributors to the increase in HL consumption in the region were China (an increase of 16.5 million barrels per day) and India (an increase of 5.4 million barrels per day). However, even with this demand dynamic, the specific consumption of HL in developing countries is still significantly lower than that in developed countries. Thus, according to OPEC and UN data, in 2024, annual per capita LHC consumption in the United States was 21.7 barrels, in the Republic of Korea – 18.0 barrels, in Japan – 9.3 barrels, in Germany – 9.0 barrels, while in Nigeria – 0.8 barrels, in India – 1.4 barrels, in Indonesia – 2.4 barrels, and in China – 4.3 barrels. This indicates significant potential for further growth in oil consumption by developing countries, which is necessary for them to maintain rapid industrial development and achieve a standard of living comparable to developed economies.

Secondly, the geographic uneven distribution of oil resources worldwide (see Table 1) has de facto divided countries into energy surplus countries, i.e., oil exporters, and energy deficit countries, i.e., oil importers. The main net exporters of oil are the countries of the Middle East (Saudi Arabia, Iraq, UAE, Kuwait, etc.), Russia, Canada, oil-producing countries of Central and South America, and Africa. The largest net importers of oil are the countries of the Asia-Pacific region and Europe [1].

Table 1. Countries' share of global oil production, exports and imports, 2024

Countries that are the largest oil producers	%	Countries that are the largest net exporters of oil	%	Countries that are the largest net importers of oil	%
USA	18,9	Saudi Arabia	14,9	China	25,7
Russia	11,6	Russia	11,3	USA	15,2
Saudi Arabia	11,2	Canada	10,2	India	11,1
Canada	6,4	Iraq	8,3	Republic of Korea	6,4
Iran	5,2	UAE	8,5	Japan	5,3
Iraq	4,7	Brazil	4,1	Germany	3,6
Total for the group of countries	58,0	Total for the group of countries	57,3	Total for the group of countries	67,3

Sources: Statistical Review of World Energy 2025. Energy Institute. <https://www.energyinst.org/statistical-review> (accessed on January 18, 2026); Trade Map – International Trade Centre (ITC). <https://www.trademap.org/> (accessed on January 18, 2026).

Middle Eastern oil exports are currently largely oriented toward Asia (approximately 85% in 2024). The US and European shares in 2024 were 2.9% and 8.8%, respectively.

Oil exports from the CIS, including Azerbaijan, are primarily directed in two directions: to Asia-Pacific countries (approximately 60% of all CIS oil exports in 2024) and to Europe (approximately 33%). However, just five years ago, in 2019, a significant portion of CIS oil exports (approximately 70%) was oriented westward.

Russia has played a key role in this reorientation of oil export flows in Eurasia, accounting for the majority of CIS oil exports: in 2024, Russian exports accounted for 73% of regional oil exports. The eastward reorientation of export flows had been planned and implemented for quite some time, since the

commissioning of the Eastern Siberia – Pacific Ocean (ESPO) pipeline in late 2012. However, in 2022, with the introduction of Western sanctions against Russian energy, the reorientation of Russian energy flows accelerated significantly.

With the development of oil production in shale regions and the lifting of the ban on oil exports in 2016, the United States significantly increased oil supplies – from 2.7 million tons in 2006 to 198.3 million tons in 2024. Most of these volumes went to European countries: 95.8 million tons, or 48.3% of all US oil exports, were sent there in 2024. The supply of such a large quantity of American oil to Europe became possible, in part, due to European countries being forced to limit their imports of Russian oil for political reasons, starting in 2022. As a result, the US share of European oil imports increased from 11% (51.4 million tonnes) in 2021 to 21% (95.8 million tonnes) in 2024. Russia's share of European oil imports decreased over this period from 30% (138.7 million tonnes) to 6% (29.6 million tonnes) [1]. During this period, European countries' imports of Azerbaijani oil increased, reaching 23.6 million tonnes in 2024.

The geographic uneven distribution of oil resources, on the one hand, and the significant heterogeneity of countries in terms of economic development, on the other, determine the current appearance of the global oil market. This market is characterized by a high concentration of both consumers and producers, as well as their significant interdependence. This means that the application of diversification strategy by both large consumers and large suppliers of oil is significantly limited at the current stage, and therefore key market participants are relatively vulnerable to external manipulation.

USA in the global oil market: evolution of instruments of influence and control

As the world's largest oil consumer, the United States has always sought to establish control over oil flows and the global oil market, often leading to crises and armed conflicts in oil-related regions. Although the "shale revolution" has radically improved the United States' hydrocarbon balance, maintaining control over key global transportation arteries and oil flows remains a priority. Losing control of these important logistical systems could weaken the United States' dominant role in the energy, economic, and financial spheres. Accordingly, the US government is seeking to strengthen its influence in strategically important energy markets to maintain its control, exploit the vulnerabilities of other major players, and further block Middle Eastern, Russian, Chinese, and other initiatives to build more equitable relations.

Over the past century, US control over the global oil market has evolved from direct resource management to a complex system of influence through monetary policy, financial infrastructure, and international institutions. One of the tools for influencing the global oil market is price control.

Pricing in general can be explained through the prism of two conceptual approaches: the labor theory of value and marginalism. Their synthesis in neoclassical theory suggests that the equilibrium price is formed at the intersection of supply and demand [2]. In the case of non-renewable natural resources, an extracting company can expect to extract Ricardian rent, defined as the difference in the costs of extraction and transportation to the consumer between different deposits, and Hotelling rent—a premium for resource scarcity under conditions of limited supply [3]. In the physical energy market, these concepts define a "price corridor," where the lower boundary is determined by production costs (cost-plus), and the upper boundary is determined by the marginal utility of the buyer (the cost of substitution with alternative energy sources). However, these theoretical foundations of pricing can only partially explain the history of price changes in the global oil market.

From the signing of the Achnacarra Agreement in 1928 until the early 1970s, the seven-company oligopoly (the "Seven Sisters") of the International Petroleum Cartel (IPC) set prices unilaterally, with the dominant pricing mechanism being cost-plus pricing tied to the costs of marginal producers in the United States. Outside the United States, the majority of global production was provided by the production units of the IPC companies. The low cost of producing Middle Eastern oil (around \$2 per barrel), while simultaneously selling petroleum products to end consumers at market prices, ensured these companies obtained excess profits through the effective appropriation of natural resource rents.

The IPC lasted 45 years, which is 5-10 times longer than the average lifespan of cartels in the 20th century [4]. The oligopoly was maintained thanks to the complete lack of transparency in the market and concession agreements—the transfer of subsoil rights without development obligations—that blocked new players from entering the market. Following the formation of OPEC in 1960 and the nationalization of IOC assets by OPEC countries in the 1970s, the monopolistic pricing of the IOC cartel was replaced by essentially the same cartel pricing, but this time by OPEC countries [5], which coordinatedly reduced oil supplies in an effort to increase their revenues by maintaining high official selling prices.

The limited global oil supply necessitated a transition from cost-plus transfer pricing to a spot market [6]. While in the first half of the 1970s, one-off spot transactions accounted for no more than 5–8%

of international oil trade, in the first half of the 1980s, they accounted for at least 40–50% [7]. Meanwhile, in 1974–1975, The United States entered into an agreement with Saudi Arabia under which oil was sold exclusively for dollars, with excess petrodollars being used to purchase US Treasury bonds and assets. This tied demand for the dollar to global oil trade, making it an indispensable global currency.

In the mid-1980s, oil-importing countries began to implement measures against OPEC's dictates, including the formation of strategic and commercial oil reserves to cushion supply disruptions, the creation of the IEA, and the substitution of oil with alternative energy resources. Moreover, a surplus of alternative supply emerged due to a significant increase in non-OPEC oil production. The presence of numerous alternative oil suppliers facilitated a gradual market transition from spot pricing to net-back pricing—the cost of replacement at the end consumer. Oil pricing shifted to exchanges and became decoupled from the real oil economy. Currently, the volume of "paper" oil (traded contracts) is many times greater than the volume of physical oil, making the market vulnerable to speculative attacks and manipulation through the distortion of trade information, collusion between major market participants, spoofing, etc.

The organization of trade and pricing of energy resources and other commodities is the foundation for maintaining the purchasing power of the US dollar internationally. Just as any instrument has its scope of application, the US's influence on the global oil market through the entities and exchange facilities it controls has its limitations. When the effectiveness of such influence proves insufficient, the US resorts to management and restrictions at the political or even military level.

Over the past 100 years, economic sanctions have become a crucial tool for achieving foreign policy goals. They are primarily used by developed countries with a strong economic and technological base. The US has become the leading initiator of sanctions: out of 174 cases of sanctions in the 20th and early 21st centuries, it imposed 1,000 sanctions. America accounts for 109 cases. Its economic dominance and leading role in global finance enable the United States to exert pressure on economically weaker players, extracting concessions on foreign and domestic policy issues.

According to SWIFT, as of the end of 2025, the US dollar is the primary currency for international trade settlements between countries, accounting for approximately 80%. It also accounts for nearly 60% of the world's foreign exchange reserves. The dollar's status as a global reserve currency and the primary international trading currency provides the United States with numerous advantages – from the ability to finance significant payments and budget deficits through inflation-free emission, i.e., effectively free credit from third countries, to control over a significant portion of global financial and trade flows. However, there is a downside: the United States is forced to increase the dollar money supply proportionally to the growth of global trade, which has long outpaced the growth of the American economy.

Given the accumulating imbalance, three possible scenarios are possible. In the first scenario, the US could continue to expand the dollar money supply to support international trade, which would lead to a doubling of the current US debt-to-GDP ratio in approximately 15-20 years. The accumulated volume of unbacked dollar money would become unmanageable, making the country extremely financially vulnerable to any external shocks. The second scenario assumes that the US abandons the dollar's dominance in international settlements and reserves and, as a result, loses all the benefits of its status as a global currency, and with it, all its competitive advantages in international trade. And the third scenario is that the US could attempt to curb the growth of international trade by imposing sanctions and trade restrictions under any pretext against major trading partners, while simultaneously seeking to accelerate the growth of its own economy through capital inflows from other countries. By threatening to impose sanctions, the US would continue to aggressively promote its currency as the primary means of international trade. Which scenario the US is pursuing is quite clear. As a result of this choice, the energy, foreign trade, and technological development of countries whose economic potential or development prospects drive the global economy and trade have become the priority targets of Western, primarily American, sanctions. A striking and illustrative current example is Western Europe, which, thanks to relatively accessible and inexpensive Russian energy resources, was able to increase its economic and financial potential by the early 2020s to such an extent that it became comparable to the United States, and the euro began to pose a certain threat to the dominance of the US dollar in international settlements and reserves. However, as a result of consistent and systematic steps by the United States in shaping sanctions policy against Russia, with the active support of EU authorities, Europe has lost one of its key competitive advantages – stable and affordable supplies of Russian hydrocarbons. The European Union spent over €550 billion on gas imports between 2021 and 2025. This is comparable to Europe's total expenditure on gas imports over the previous 14 years, when Russia was the leading supplier of gas to Europe. Energy shortages and price volatility in energy markets have led to deindustrialization—the shutdown of

industrial production or the relocation of manufacturing operations from Europe to other countries. Energy-intensive industries in European countries, such as chemicals, glass, metal, fertilizer, ceramics, cement, pulp and paper, and the automotive and mechanical engineering industries, have been hit particularly hard. As a result, EU countries, primarily Germany, are losing their status as global technology leaders and leading manufacturers.

This example clearly illustrates how important control over the global energy market is for the United States. The United States has always sought and will continue to seek to limit or at least control both third-country energy sources (because they can potentially develop independently of the United States) and energy trade (because partner countries receiving energy resources can develop).

Sanctions and other restrictions imposed under trumped-up pretexts against certain energy-exporting countries enable the United States to achieve several goals at once. First, gradually ousting competitors from the energy market allows American companies to increase their own production and exports of energy resources. Second, such a strategy reduces the income and economic potential of the United States' direct competitors in the energy sector. Third, it increases the energy and economic dependence of energy-deficit countries on US policy and hinders their development.

The colonial nature of Western sanctions is clearly evident in the cases of Iran and Venezuela. Thus, in response to Iran's increasing demands for consideration of its national interests and the nationalization of the Anglo-Iranian Oil Company in the 1950s, Great Britain, with US support, imposed a boycott on Iranian oil and petroleum products. The sanctions were soon followed by an American and British intelligence operation to overthrow Iranian Prime Minister Mohammed Mossadegh. Less than a year after his overthrow, the International Consortium for the Development of Iranian Petroleum was formed, with a 40% stake held by a British company, 40% by a group of American firms, 14% by Shell, and 6% by French shareholders. The modern history of sanctions against Iran, beginning in 1979, is characterized by an ever-increasing scope and severity of the imposed restrictions. In 1996, the US Congress passed the Iran Sanctions Act against Iran, which primarily targeted Iran's energy sector. It prohibited major investments in the Iranian energy sector, the supply of technology, vessels, and the provision of transportation and insurance services for petroleum products.

In addition to pressure on Iran, Washington has consistently increased sanctions against another oil exporter: Venezuela. Along with sanctions against the Venezuelan government, beginning in 2017, the US imposed restrictions on the Venezuelan state-owned oil company PDVSA. Given the importance of oil export revenues for the country, pressure on PDVSA meant an inevitable reduction in export revenues and the degradation of the oil industry. In late 2025, the US effectively imposed a naval blockade on Venezuela and seized several tankers. On January 3, 2026, US forces invaded Venezuela and captured President Nicolás Maduro. The real goals of this operation were subsequently revealed by both US President Donald Trump himself and Secretary of State Miguel Rubio. First, the US sought to prevent Venezuela's cooperation with America's main strategic rivals (China, Iran, and Russia) and, second, to regain control of Venezuela's oil resources. President Trump has repeatedly accused Venezuela of "stealing American assets," particularly in the oil industry, in his public statements. After Maduro's overthrow, the US effectively established control over Venezuela's oil and gas sector.

In 2014, the West launched a just sanctions war against Russia in response to its violation of international law in Ukraine. To date, more restrictions have been imposed than on Iran, Venezuela, Syria, and North Korea combined. One of the main blows has been to Russia's energy sector and its ability to export energy. The first country to impose a ban on imports of Russian energy products, including oil and petroleum products, was the United States of America – US President Joe Biden signed the corresponding decree on March 8, 2022. In early June 2022, the European Union adopted another package of sanctions against Russia, which included a ban on seaborne imports of oil from the Russian Federation, starting from December 5, 2022, and petroleum products, starting from February 5, 2023. This sanctions package also prohibited European companies from providing "technical assistance, intermediary services, or financing or financial support" (including insurance and reinsurance) for the transportation to third countries, including ship-to-ship transshipment, of oil and petroleum products of Russian origin. On December 2, 2022, the G7 countries and Australia reached an agreement to introduce a price ceiling of \$60 per barrel on seaborne oil exports from Russia to third countries, starting from December 5. Similar restrictions were announced regarding Russia's export of petroleum products, for which a the price ceiling was renewed at \$100/bbl for diesel, gasoline, gasoil, vacuum gasoil, and jet fuel, and at \$45/bbl for fuel oil and naphtha.

In the second half of 2025, as part of the latest, 18th, package of anti-Russian sanctions, the EU lowered the price ceiling on Russian oil to \$47.6/bbl. The UK, Norway, Japan, and New Zealand joined

the restrictions. The imposed restrictions allowed European companies to provide trading, brokerage, and transportation services for the transport of Russian oil to third countries only if the purchase price of the oil in Russia was not higher than the established level. According to recommendations from the US and UK, fines will be levied on buyers, sellers, traders, and brokers found to have violated the introduced price cap on Russian oil. These actions constitute nothing less than an unprecedented intervention by the US and EU in the global oil market and an attempt to expropriate a portion of natural resource rents.

To increase its share of the global oil market without losing profitability, the US constantly needs to strengthen its competitive advantages.

Another tool of Western policy is the promotion of false narratives under the auspices of Western-controlled international organizations. Among these, for example, is the idea of an energy transition. It is aimed primarily at strengthening the unipolar structure of the world order with Western civilization as the dominant force, discriminating against the rest of the world, and extracting technological rents. At its core, the "green" transition is yet another form of neocolonialism against developing and undesirable countries. The announced energy transition program is a powerful, well-worn sanctions barrier for 88% of the world's population—for everyone who is not part of the "golden billion," or who should be excluded from it. These are, in essence, undeclared sanctions that are being implemented [8]. At the same time, the West in general, and the United States in particular, refuse to accept any responsibility for the significant volume of greenhouse gases emitted into the atmosphere by their industries over the past century. It is significant that the Trump administration opposes not the "green" transition in general, but its implementation on American soil and the associated international obligations, recognizing that this will not bode well for the American economy.

Thus, the US strategy is to consistently hinder the energy and technological development of potential competitors, gradually reducing both their numbers and their capabilities. Consequently, all partner countries receiving reliable, affordable supplies of oil and petroleum products from Iran and Russia are also at risk.

Azerbaijan's oil and gas industry in the new environment: maximizing market opportunities

Oil constitutes a significant portion of Azerbaijan's national income and the bulk of its economic potential. Since 1994, implementing a new oil strategy has become a priority of the country's foreign policy. The primary objective of this strategy was the rational use of advanced Western technologies and investment opportunities, ensuring the development and production of the rich hydrocarbon reserves in the Azerbaijani sector of the Caspian Sea. The next challenge was to transport these reserves safely to world markets, and with the proceeds from their sale, to develop other sectors of the country's economy and ensure the well-being of current and future generations.

If we simply classify the competitive methods currently used in the global market, we can identify several main types: unfair competition, fair price competition, and fair non-price competition. Previously, in an effort to restrain the development of socialist countries and then developing countries, the West primarily used fair competition methods due to their economic weakness. However, in recent years, amid the growing economic power of several developing countries and their inability to successfully compete with them, Western countries have resorted to outright violation of established international trade rules and the use of unfair competition. Unfair competition involves the use of non-market restrictive measures that deprive other market participants of the opportunity to conduct transactions.

Given the current situation in the global oil market, Azerbaijan has accelerated the diversification of its oil and petroleum product export routes. Accelerated, as Azerbaijan as a whole, and SOCAR in particular, have already been engaged in long-term, systematic, and successful work in this direction. Recognizing that the European market offers the greatest potential for increasing energy consumption, Azerbaijan has initiated and implemented a number of infrastructure and investment projects that facilitate the reliable and cost-effective supply of Azerbaijani hydrocarbons to the West. The steps taken by Azerbaijani companies to ensure sustainable energy supplies, strengthen long-term partnerships, and support socioeconomic development are attracting the keen interest and full support of partners in developed countries, strengthening Azerbaijan's position internationally and creating markets for Azerbaijani energy resources. To increase energy access in developed and developing countries, Azerbaijan combines various formats of interaction with partners, ranging from direct exports of Azerbaijani energy resources to the establishment of long-term partnerships aimed at localizing and jointly extracting energy resources, developing logistics infrastructure and energy production, providing financial support, and more. Although some steps taken by Azerbaijan have not been successfully implemented, primarily for reasons beyond the control of the parties involved, they have nonetheless contributed to the expansion of

Azerbaijan's business opportunities through the formation of new business connections, business ideas, projects, and the strengthening of trust.

The Azeri-Chirag-Guneshli strategic oil and gas infrastructure project in the Khazar Sea is an example of joint efforts between Azerbaijan and national oil and gas companies from leading countries. It is no coincidence that, at this stage, an oil strategy is an integral part of Azerbaijan's domestic and foreign policies aimed at addressing socioeconomic and international challenges. The foundation of this strategy was laid by the signing of a contract on September 20, 1994, between the State Oil Company of Azerbaijan (SOCAR) and a consortium of major foreign oil companies for the joint development of the Azeri and Chirag offshore fields and the deepwater portion of the Gunashli field in the Azerbaijani sector of the Caspian Sea, and the distribution of produced oil on a shareholding basis. The consortium, along with SOCAR, included ten major companies from six countries: Amoco, Unocal, Pennzoil, McDermott (USA), British Petroleum, Remco (UK), Lukoil (Russia), Statoil (Norway), TPAO (Turkey), and Delta (Saudi Arabia). Based on the number of participating major companies representing the world's leading countries, the volume of capital investments, and its geopolitical significance, this agreement was dubbed the "Contract of the Century." To date, within the framework of Azerbaijan's oil strategy, the foundation of which was laid by the "Contract of the Century" in 1994, a total of 27 oil agreements have been signed with foreign oil companies. The number of promising structures envisaged for joint use by these agreements is 30. 15 of these the agreements cover the Azerbaijani sector of the Caspian Sea, and 12 cover onshore areas. The Azerbaijani government's partners in these agreements include 43 companies representing 21 countries.

Energy cooperation is not limited to oil and gas companies. Other Azerbaijani energy companies are also participating in fuel and energy projects in developing countries.

Assessing the prospects for the development of liquid hydrocarbon markets, strengthening relations with Turkey, Georgia, and other neighboring states is particularly noteworthy. The oil strategy has created the petrochemical and oil refining industries, which form the foundation of the national economy, and the infrastructure of related sub-fields that meets modern standards. Taking advantage of the extensive experience and contingent of specialists in the oil refining and oil processing sectors, the Azerbaijani government has begun to invest heavily in these areas abroad. A giant oil terminal in Georgia and an oil refinery in Turkey are currently owned by the State Oil Company of Azerbaijan, which represents the Azerbaijani government. Azerbaijani oil workers and engineers took on the exploration and production of oil fields in Moldova.

Large projects implemented as part of Azerbaijan's oil strategy for transporting Central Asian oil and natural gas to Europe—the Baku-Tbilisi-Ceyhan oil pipeline and the Baku-Tbilisi-Erzurum gas pipeline—are cited as key prerequisites for the emergence of such large-scale projects as Transkhazar and Nabucco, which remain unrealized to this day.

SOCAR acquired the Petkim petrochemical complex in Turkey and built the Star Oil Refinery in Izmir, driven by its interest in a reliable market for its oil and petroleum products. Thus, each party gained both opportunities and guarantees for maintaining reliable trade relations. A strong supplier-consumer relationship was established, with a win-win outcome: the supplier is guaranteed a market, and the consumer a reliable supplier at a reasonable price. One of the next steps to strengthen trade ties was the conclusion of long-term oil supply agreements, and a program was agreed upon for the development of strategic areas of economic cooperation between the two countries until 2036, as well as for the development of logistics along the Silk Road international transport corridor [9].

Thus, Azerbaijan has actively applied and continues to successfully apply fair competition tools to increase its share in new markets. Fair price competition consists of ensuring a reliable channel of guaranteed supplies at a price acceptable to consumers.

When assessing the effectiveness and efficiency of Azerbaijan's oil export reorientation, factors such as oil price and export volumes cannot be ignored. Based on Azeri Light quotes, which are established in the oil market, oil from Azerbaijan has been supplied to Italy at prices above the price ceiling since at least the summer of 2023, demonstrating the correctness of the actions of Azerbaijani oil companies.

The new Azeri Light price exceeding the market-set price ceiling for Azerbaijani oil is not surprising and is due to the fact that the global oil market as a whole has maintained its link to changes in the global economy.

Theoretically, the effectiveness of the regulatory (balancing) function of price through the arbitrage mechanism depends both on the size of the interregional price spread and the overall balance of the global oil market. As for the fundamental balance of oil supply and demand on the global market, it

was maintained during this period by OPEC+ participants fulfilling their oil production targets and making voluntary commitments to further reduce production within the framework of this agreement. The continued small supply deficit of 0.1–0.3 million barrels per day in 2022–2024 generally contributed to the effectiveness of the arbitrage mechanism.

It is worth emphasizing that the dynamics of Azerbaijani oil production and exports in the period 2022–2025 will be significantly lower than expected. The oil production situation was determined by Azerbaijan's fulfillment of its obligations under the OPEC+ production cut agreement. Azerbaijani companies fully complied with their contractual obligations both with foreign partners and in the domestic market. There was no significant decline in Azerbaijani oil production and export volumes. By 2025, oil production had decreased slightly to 27.7 million tons, which is 19.7% lower than the 2020 level. Azerbaijani oil exports in 2025 also decreased by 17.6% and amounted to 82.4% of the 2020 oil export level (see Table 2).

Table 2. Oil production and export in Azerbaijan (2020–2025)

	2020	2021	2022	2023	2024	2025
Oil production, million tons	34.5	34.6	32.6	30.1	29.1	27.7
in % to the previous year	92.0	100.3	94.2	92.3	96.7	95.2
Oil exports, million tons	28.4	28.1	26.6	26.1	24.4	23.4
in % to the previous year	97.5	98.9	94.7	98.1	93.5	95.9

Source: Statistics Committee data, 2025 (stat.gov.az).

When discussing the effectiveness of Azerbaijan's strategy and tactics in the oil market, we cannot ignore the issue of the budgetary effectiveness of the steps taken. A closer look at the dynamics of the oil portion of oil and gas revenues reveals the following. In 2020, total revenues to the state budget amounted to 12.2 billion manat, an increase of 8.3% compared to 2021. The price factor played a positive role here. Of course, this increase was partly due to the increase in oil prices, which amounted to 2% and 7.6%, respectively (see Table 2). In 2022, the volume of revenues from the oil portion of oil and gas revenues to the state budget decreased to 7.9 billion manat, or by 31.2% compared to 2021, which was mainly due to global price volatility and, in particular, a decrease in the global average annual price of Azeri Light oil by 18.2%, to \$83 per barrel, rather than a reduction in oil production and export volumes. However, already in 2023, despite a slight reduction in oil production and exports in Azerbaijan as part of the OPEC+ agreement, oil revenues to the state budget increased by almost 48.1% and exceeded 11.7 billion manat, approximately 7.5% higher than the 2022 level.

The completion of the tax maneuver, which redistributes the tax burden from oil exports to oil production, certainly had some impact on the growth of oil tax revenues to the state budget in 2024. As part of this tax maneuver, revenues from duties on oil and petroleum products exports were consistently reduced from 2019 to 2023, with the duty rate being completely reduced to zero in 2024, while revenues from the mineral extraction tax on oil increased accordingly.

In 2025, due to lower oil prices and the strengthening of the manat, the mineral extraction tax (MET) on oil was reduced. State budget oil and gas revenues increased by 9.3% compared to 2024 levels, reaching 18.8 billion manat.

In 2026, the Azerbaijani Ministry of Finance plans to collect 8.5 billion manat in oil and gas revenues, assuming an average annual Azeri Light price of \$75 per barrel and an exchange rate of 1.70 manat per US dollar. This volume is expected to be below the baseline, resulting in a budget shortfall of 10.5 billion manat.

Azerbaijan's strategy in energy markets is cooperation and development

Azerbaijan's current strategy in energy markets in general, and in the oil market in particular, has largely maintained its position. Thanks to its resource potential and geographical location, Azerbaijan plays a special role in the development of energy complexes along the Turkey-Italy-Balkan countries vector, making a significant contribution to maintaining a stable balance of hydrocarbon supply and demand on international markets.

Recognizing and understanding the historical inevitability of the emergence of new centers of power in the world as they accelerate economic development, Azerbaijan has abandoned bloc-based thinking. An ideologically based bloc approach entails a certain limitation of political sovereignty for participating countries, significantly limiting the number of potential partner countries.

Under these circumstances, the most effective strategy for countering the fading monocentric world model can only be to increase the number of centers of power and countries that surpass it in terms of development rates. Globalization has facilitated the involvement of more countries in the process of rapid economic growth, which has become the historical basis for the transition to a polycentric

world, where various centers of power compete with each other and formulate independent strategic decisions. It is precisely this "club" approach, based on mutually beneficial cooperation based on national interests, that is the most promising and capable of attracting a significant number of potential participants. The relevance and demand for this historically inevitable process is reflected in the ever-increasing number of countries wishing to participate in the work of such associations, whose organization offers participants the opportunity to develop and strengthen economic and political ties based on equality and mutual benefit, as well as to address global problems through joint efforts.

For accelerated economic growth and industrial development, many energy-deficient countries require reliable supplies of energy resources at affordable prices. In 2015, the international community set an ambitious goal – "Ensuring universal access to affordable, reliable, sustainable, and modern energy for all" – with the goal of achieving it by 2030. Azerbaijan's primary strategy in the global oil market is to participate in international initiatives related to the sustainable development of global energy, ensuring energy security both domestically and internationally. This includes ensuring a stable energy supply, reducing energy supply risks, and improving the efficiency of Russian energy companies' foreign trade activities.

Azerbaijan is pursuing a hybrid shift: maintaining its status as a reliable hydrocarbon supplier to Europe and Turkey while accelerating the transition to green generation and electricity exports. Key pillars include cross-border infrastructure (BTC, Southern Gas Corridor), long-term agreements with the EU and Turkey, participation in OPEC+ for the global market, and large-scale renewable energy and "green zones" projects. The vector is non-confrontation, institutionalized cooperation, and integrated development. Azerbaijan's Strategy in Energy Markets:

I. Strategic Objectives:

- Energy security partners: security of supply and favorable pricing/volume regimes.
- Diversification: sales markets, product lines (gas, oil, petrochemicals, renewable energy power), financial sources, and routes.
- Integration into green value chains: scale of renewable energy, green electricity exports, conversion of gas products to low-carbon molecules.
- Fiscal sustainability and industrialization: use of oil and gas revenues to develop refining, petrochemicals, and new industries.

II. Hydrocarbon base

- Oil: ACG (Azeri-Chirag-Guneshli) cluster, export via Baku-Tbilisi-Ceyhan (BTC) and Baku-Supsa. SOCAR's role in trading and logistics ensures commercial flexibility.

- Gas: Shah Deniz is the anchor of the Southern Gas Corridor (SGC: SCP–TANAP–TAP). Supplies to Turkey, Georgia, and Southern/Central Europe. From 2022. - Focus on increasing export volumes to the EU by 2027 (expansion of TAP to 20 billion cubic meters per year and TANAP to ~31 billion cubic meters per year).

- Regional schemes: proposals with Iran and Turkmenistan for demand flexibility; potential trans-Caspian synergies remain controversial, despite the presence of a commercial and political basis.

- Market and coordination: participation in OPEC+ agreements as a tool for preserving and supporting the investment cycle. III. Vectors of Cooperation

- EU: 2022 Memorandum on doubling gas supplies by 2027; joint research on decarbonization of the SGC (methane reduction, readiness for H2 blending).

- Turkey and Georgia: developed transit and market partners; deepening downstream integration (SOCAR in Turkey: Petkim, STAR) and electricity cooperation.

- Central and Southern Europe: expansion of TAP and interconnectors (Italy, Greece, Albania, Bulgaria, Romania, Hungary) for flow flexibility and seasonal optimization.

- Middle East and Asia: renewable energy partnerships and financing (Masdar, ACWA Power), technology consortia, access to green capital. IV. Development of renewable energy and green corridors:

- Targets: By 2030, approximately 30% of installed capacity will come from renewable energy sources; priority will be given to wind and solar generation, including offshore and offshore wind (significant potential in the Caspian Sea).

- Projects: Packages with Masdar and ACWA Power (wind/solar, phased delivery at the Gobi sites and Caspian locations). Creation of "green zones" (Karabakh, Eastern Zangezur) with preferential infrastructure. - Electricity Exports: Black Sea/Green Energy Corridor initiatives (Azerbaijan–Georgia–Romania–Hungary) for the transmission of "green" electricity to the EU via HVDC. V. Medium-Term Forecast (to 2030)

- Gas: Gradual increase in supplies to the EU with stable completion of expansion investments and a confirmed resource base (Shah Deniz, possible upsides in Absheron, etc.).
- Oil: Stable/moderately declining profile with an emphasis on efficiency and carbon footprint reduction.
- Renewable energy and electricity: Fast-growing segment, emergence of electricity export flows to the EU; preparation for offshore wind.
- Integration: Deepening the links between "gas as a fuel bridge and a growing share of renewable energy," which increases resilience to shocks.

Azerbaijan, as a responsible participant in international relations, continues to adhere to its commitments to supply energy resources to developed European countries. Azerbaijan is also interested in expanding its participation in international efforts to ensure sustainable development of the global energy sector. Azerbaijan initiates and implements large-scale energy infrastructure projects that connect regional countries. Through this, Azerbaijan ensures essential energy supplies to those in need. This is especially important today, when energy security is becoming a key factor in the national security of every state.

Under these circumstances, achieving the strategic objective of strengthening Azerbaijan's position in international hydrocarbon markets is impossible without fully diversifying its energy supply routes to benefit the rapidly growing markets of friendly countries.

Conclusion

Based on the overall analysis, it is reasonable to conclude that the strategic and tactical decisions Azerbaijan has made in various oil market situations, including crisis ones, have proven correct. This enabled a timely reorientation of oil flows and prevented a significant decline in Azerbaijani oil production and exports, which ensured the sustainability of Azerbaijan's budget system through relatively stable revenues from the oil portion of oil and gas revenues.

Based on the analysis, the following recommendations can be made:

- Accelerate the expansion of the Southern Gas Corridor (SGC), while simultaneously reducing methane emissions and preparing for H2 blending.
- Close long-term offtake contracts and financing for renewable energy and the HVDC corridor across the Black Sea.
- Expand the petrochemical portfolio and localize services to deactivate the multiplier.
- Strengthen ESG reporting and verification to reduce the cost of capital and mitigate regulatory risks in the EU.
- Develop "green zones" as pilot projects for energy storage, smart grids, and local balancing markets.

Based on the analysis, Azerbaijan's strategy in energy markets is institutionalized cooperation and phased development: from reliable gas and oil products to low-carbon energy exports and future infrastructure, with an emphasis on partner competitiveness and the sustainability of its own economy.

References

1. Statistical Review of World Energy 2025. Energy Institute. London, 2025. <https://www.energyinst.org/statistical-review/home>.
2. Marshall A. Principles of Economics. 8th ed., London: Macmillan and Co., 1920.
3. Hotelling H. The Economics of Exhaustible Resources. Journal of Political Economy. 1931. Vol. 39(2). Pp. 137–175.
4. Levenstein M.C., Suslow V.Y. What Determines Cartel Success? // Journal of Economic Literature. 2006. Vol. 44. No. 1. Pp. 43–95.
5. Aliyev I. Caspian oil of Azerbaijan. - M.: Izvestia, 2003. - 712 p. ISBN 5-206-00618-1 (In Russian).
6. "Azərbaycan 2020: Gələcəyə Baxış" inkişaf konsepsiyası // – Bakı, 2012-ci il.
7. Orucov M.M. İbrahimova S.R. Azerbaijani economy during İlham Aliyev's presidency: a long way traveled in 20 years, Scientific and Pedagogical News of Odlar Yurdu University, 2023, № 63, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552
8. Orucov M.M. İbrahimova S.R. Monetary stabilization policy the financial crisis, XIV international scientific conference. Tokyo. Japan. 31.10-01.11.2024 ISBN 978-92-44514-26-9 DOI <https://doi.org/10.5281/zenodo.14046748>
9. Orucov M.M, Modern development model of the national economy, Scientific and Pedagogical News of Odlar Yurdu University, 2020, № 54, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552 (in

Azerbaijan)

10. Orucov M.M, *The current state of the Azerbaijani economy against the backdrop of changes in the world economy*, Scientific and Pedagogical News of Odlar Yurdu University, 2018, № 50, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552

11. Orucov M.M. *Prospects for international settlements in digital currencies of Central Banks on a platform basis in foreign countries and Azerbaijan*, XVIII International Scientific and Practical Conference. Paris. France. 18-19.03.2025, ISBN 978-91-65424-12-8 DOI <https://doi.org/10.5281/zenodo.15095044>

12. «Azərbaycan 2030: sosial-iqtisadi inkişafa dair Milli Prioritetlər» haqqında Azərbaycan Respublikası Prezidentinin Sərəncamı). Bakı. 40

13. Orucov M.M. *Diversification of economy the Republics Azerbaijan on the base sustainable development of non-oil sector*, XIV international scientific conference. Toronto. Canada. 14-15.11.2024, ISBN 978-92-44514-28-3 DOI <https://doi.org/10.5281/zenodo.14199182>

14. Orucov M.M. *Elements of credit policy and stimulation of credit investments in the real economy*, Sciences of Europe (Prah, Czech Republic) No 153 (2024, ISSN 3162-2364

15. Orucov M.M. *New trends and challenges to the global economy*, XIV international scientific conference. Stockholm. Sweden. 21-22.01.2025, ISBN 978-91-65424-04-3 DOI <https://doi.org/10.5281/zenodo.14749265>

16. Orucov M.M. *Forecast of global economy development*, I international scientific conference. Marseille. France. 20-21.02.2025, ISBN 978-92-44514-42-9 DOI <https://doi.org/10.5281/zenodo.14932296>

17. Orucov M.M. *Application of money supply targeting regime within the framework of monetary policy*, I international scientific conference. Seoul. South Korea. 06-07.03.2025, ISBN 978-92-44514-44-3 DOI <https://doi.org/10.5281/zenodo.15020702>

Medical sciences

PSORIASIS AND CARDIOVASCULAR PATHOLOGY: THE ROLE OF SYSTEMIC INFLAMMATION IN AORTIC ENDOTHELIAL DAMAGE AND FERROPTOSIS

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Abstract

Background: Psoriasis is a chronic systemic inflammatory disease that extends far beyond skin lesions, involving other organs and tissues [5]. The severity of the disease significantly increases the risk of cardiovascular complications, independently of traditional risk factors [3, 7]. This process is fundamentally driven by neutrophil activation and iron-dependent death of the vascular endothelium (ferroptosis) [1, 7].

Objective: The objective of this review is to analyze the molecular-immunological mechanisms of subclinical vascular inflammation in psoriasis (neutrophil activity, protein, ferroptosis) and to systematize them from the perspective of F-FDG-PET/CT diagnostics and modern biosimilar therapy options.

Results: In patients with psoriasis, active inflammation of the subcutaneous adipose tissue elevation) was recorded alongside global aortic inflammation [3]. In the blood, neutrophil activation and protein levels are sharply increased, correlating directly with vascular damage [7]. The aortic {TBR} index, serving as an indicator of vascular inflammation, was found to increase the risk of future cardiovascular events by 4.71-fold [4].

Conclusion: F-FDG-PET/CT is an effective cardio-prognostic tool for the early detection of systemic inflammation in psoriasis [3, 7]. Furthermore, the early integration of affordable biosimilars into treatment protocols stands as a key pharmacoeconomic strategy for preventing vascular complications and related comorbidities [6].

Keywords: *Psoriasis; Vascular inflammation; Aorta; Ferroptosis; F-FDG-PET/CT, Biosimilars.*

Introduction:

Psoriasis is an immune-mediated systemic inflammatory disease with a global prevalence ranging from 0.51% to 11.43%, characterized by a chronic relapsing course [6]. This condition leads to a decreased quality of life, psychological distress, and severe comorbidities that impair overall health [5, 6]. Cardiovascular disease, developing against the background of chronic low-grade systemic inflammation, represents one of the most dangerous complications in psoriasis [3].

Recent fundamental studies have revealed that a novel form of cell death—iron-dependent ferroptosis—and -mediated ferritinophagy lie at the core of atherosclerosis and vascular damage [1]. Chronic immune cascades in psoriasis activate damage, inflammation, and calcification of the inner layer of blood vessels (endothelium) [1, 2]. However, the molecular-level relationship between the severity of cutaneous psoriasis and preclinical (subclinical) changes in large arteries, as well as the pathways to suppress them using modern therapy, still requires systematic analysis.

Figure 1. Schematic representation of the pathophysiological link between psoriasis and atherosclerosis, mediated by dysfunctional HDL and inflammatory stress.

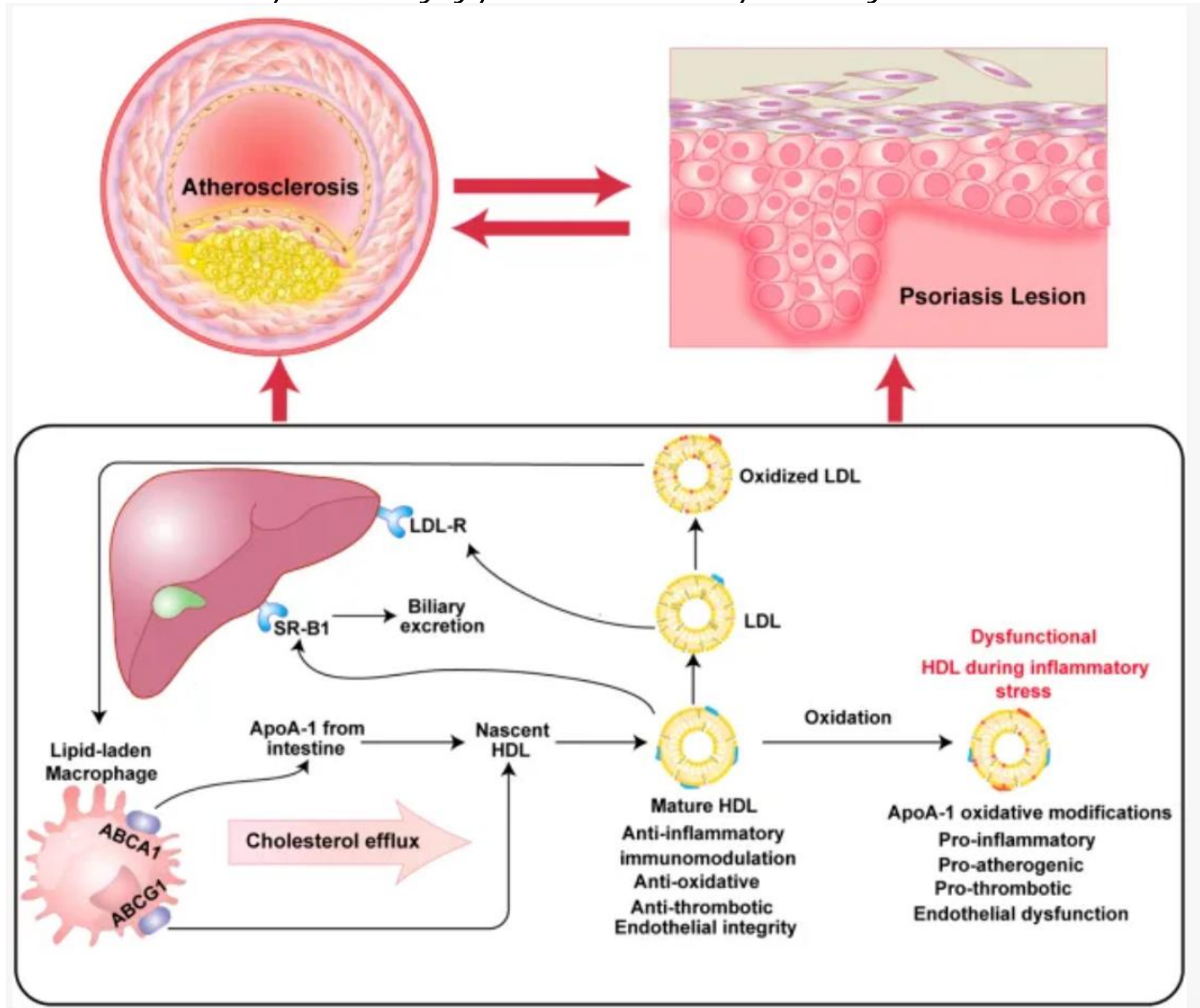
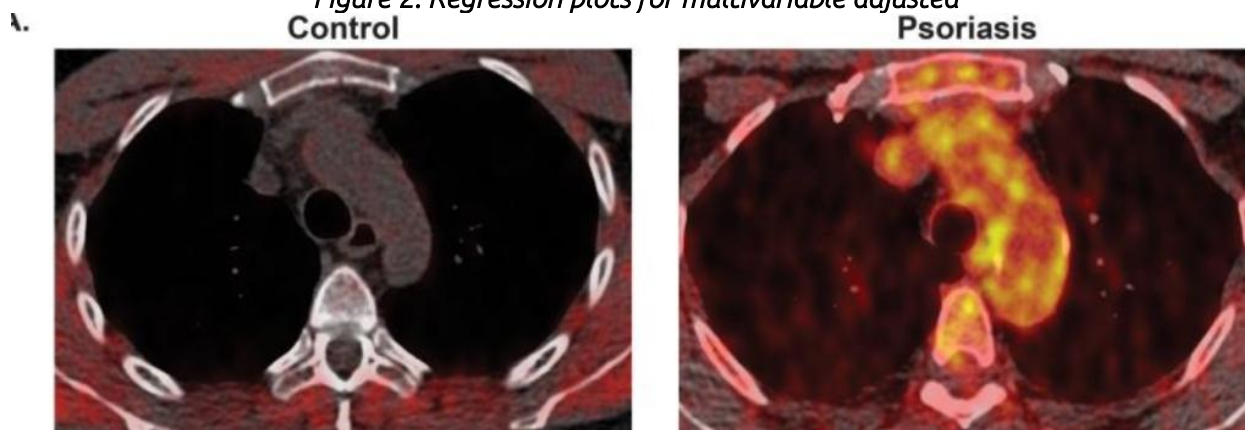
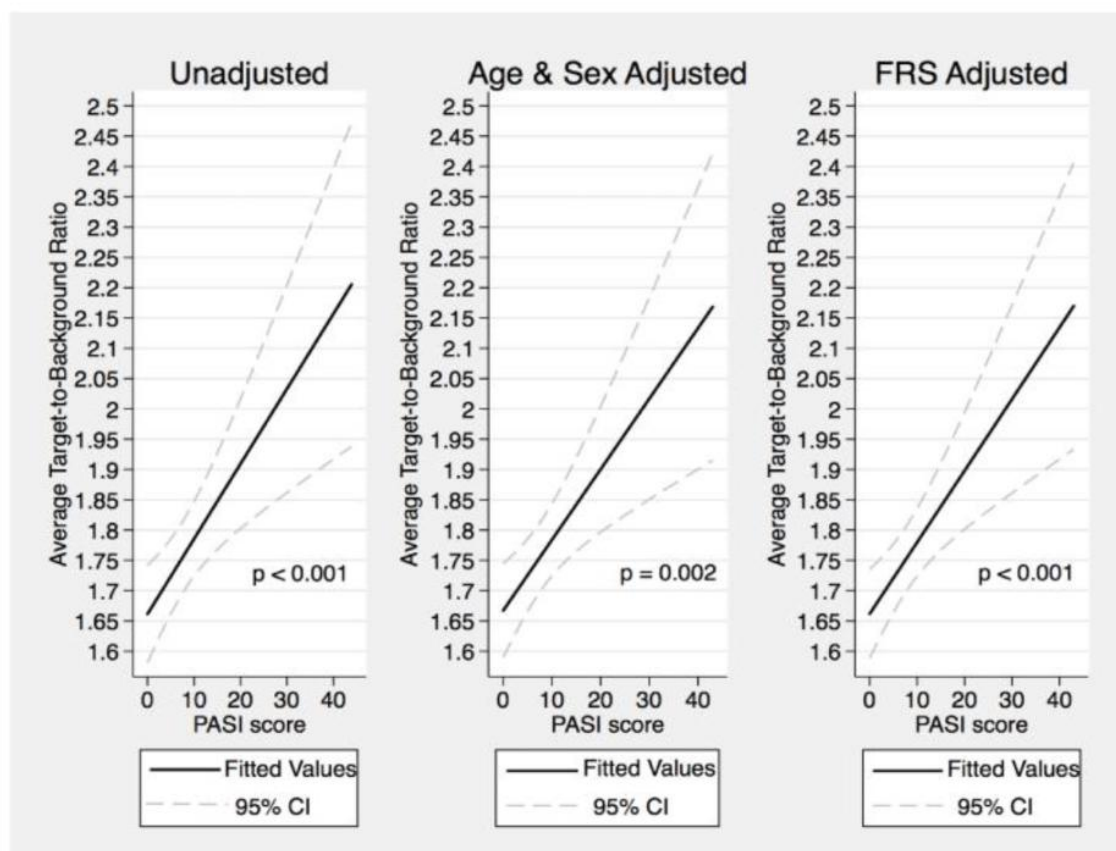


Figure 2. Regression plots for multivariable adjusted



3.



2. METHODS

In this study, a systematic analysis was conducted on fundamental and clinical research, prospective observational studies, and clinical reviews recently published in international databases including PubMed, Scopus, and Web of Science. The analysis incorporated leading international scientific works [1–7] evaluating vascular inflammation in psoriasis using positron emission tomography F-FDG-PET/CT, calculating aortic and coronary artery calcification, exploring neutrophil activity, and characterizing the molecular mechanisms of ferroptosis.

3. Results

3.1. Vascular Endothelial Damage and the Mechanism of Ferroptosis

Molecular biological studies have proven the significance of ferroptosis, caused by reduced antioxidant defense, in atherosclerotic endothelial cells [1]. The expression of (nuclear receptor coactivator 4) increases in endothelial cells, triggering a ferritinophagical reaction [1]. The upstream regulatory target of this process is the receptor for oxidized low-density lipoproteins, and its activation is directly linked to the inflammatory signaling pathway [1]. This mechanism is considered a primary reason why systemic inflammation in psoriasis disrupts the vascular wall from within.

3.2. Subclinical Vascular and Adipose Tissue Inflammation F-FDG-PET/CT

Clinical studies have shown that even when cutaneous manifestations of psoriasis are mild, sub-clinical inflammation within large arteries continues to progress [4]. On PET/CT images, a typical hallmark of thoracic aortic inflammation known as the "candy cane sign" has been identified [4].

In patients with moderate-to-severe psoriasis, the level of arterial inflammation is significantly higher than in healthy controls (the mean across the entire vessel reaches 2.46 ± 0.31 in psoriasis compared to 2.09 ± 0.36 in healthy controls; $P = 0.005$) [3]. Additionally, it was demonstrated that active inflammation of the subcutaneous adipose tissue concurrently occurs in the psoriasis group values were 0.49 ± 0.18 in psoriasis versus 0.31 ± 0.12 in healthy individuals;

$P = 0.002$) [3]. These correlations remain statistically significant independently of the patients' age and body mass index (BMI) [3].

3.3. Vascular Calcification and Neutrophil Activation

In patients with psoriasis, there is a direct correlation between the coronary artery calcification score (CACS) and the abdominal aortic calcification score [2]. These scores are significantly higher in patients presenting with psoriatic arthritis [2].

Pathophysiologically, the severity of psoriasis is closely linked to neutrophil activation in the blood, characterized by the downregulation of CD16 and CD62 markers on the neutrophil surface [7]. Serum levels of S100A8/A9 (calprotectin) (745.1 ± 53.3 vs. 195.4 ± 157.8 ng/ml in healthy controls; $P < 0.01$) and neutrophil elastase-1 are sharply elevated in psoriasis [7]. Most importantly, the S100A8/A9 protein was found to be directly associated with both cutaneous disease severity ($B=0.53$) and aortic vascular inflammation ($B=0.48$; $P=0.02$) [7].

Table 1. Comparative characteristics of clinical, laboratory, and PET/CT parameters in patient and control groups

Parameters	Psoriasis Group	Control Group	P-value	Reference
Global aortic inflammation (TBR max)	$2,46 \pm 0,31$ [3]	$2,09 \pm 0,36$ [3]	$P=0,005$	[3]
Subcutaneous adipose tissue inflammation (TBR max)	$0,49 \pm 0,18$ [3]	$0,31 \pm 0,12$ [3]	$P=0,002$	[3]
Frequency of circulating neutrophils	$3,7 \pm 1,2$ [7]	$2,9 \pm 1,2$ [7]	$P=0,02$	[7]
Serum S100A8/A9 (ng/ml)	745.1 ± 53.3 [7]	$195,4 \pm 157,8$ [7]	$P < 0,01$	[7]
Neutrophil elastase-1 (ng/ml)	$43 \pm 2,4$ [7]	$30,8 \pm 6,7$ [7]	$P < 0,001$	[7]

4. Discussion

4.1. Clinical Significance of PET/CT and the TBR Metric in Cardiovascular Prognosis

In assessing the link between psoriasis and cardiovascular risk, the target-to-background ratio (TBR) measured via F-FDG-PET/CT carries outstanding clinical and prognostic value [3, 4, 7]. An elevated aortic {TBR} level is a direct manifestation of intensive glucose consumption by macrophages and activated immune cells within the vascular wall [4, 7]. Prospective studies have proven that an elevated aortic {TBR} index—beyond the traditional Framingham Risk Score and vascular calcium scoring—increases the risk of future severe cardiovascular events, such as stroke or acute coronary syndrome, by **4.71-fold** and significantly accelerates their onset ($p < 0.0001$) [4].

Furthermore, PET/CT imaging revealed that the cutaneous severity of psoriasis (PASI score) correlates directly with the level of aortic inflammation {TBR} ($B=0.41$, $P=0.001$) [7]. This association remained robust even after adjusting for age, sex, and traditional cardiovascular risk factors, highlighting the independent, direct damaging effect of psoriasis on the vascular system [7].

4.2. Therapeutic Impact and Pharmacoeconomics of Biosimilars

Modern targeted biologic therapy alters the natural course of the disease, lowering the general inflammatory background and preventing irreversible organ damage [5]. However, the high economic cost of these drugs restricts access to treatment for many patients [6].

In this context, introducing biosimilars (biologic analogs) into the market represents an effective pharmacoeconomic strategy that reduces healthcare expenditures [6]. Biosimilars open opportunities for treating patients at an earlier stage of the disease, thereby significantly reducing PET/CT-registered vascular inflammation {TBR}, endothelial ferroptosis, and the risk of developing systemic comorbidities like calcification [1, 2, 6].

Table 2. Key pathophysiological mechanisms of vascular damage and therapeutic targets in psoriasis

Pathological Level	Core Molecular Mechanism/Markers	Clinical Consequences (Manifestation)	Treatment and Prevention Approaches	Reference Source
Molecular Level	NCOA4 and LopOX-1 activation cGAS-STING pathway[1]	Endothelial cell ferroptosis and vascular wall degradation [1]	Selective ferroptosis inhibitors, antioxidant defense[1]	[1]
Immune Level	Neutrophil activation production of S100A8/A9 (calprotectin) [7]	Acute internal aortic inflammation, chronic endothelial irritation [7]	Targeted biological therapy (TNF- α , IL-23, inhibitors)[5]	[5, 7]
Tissue&Organ Level	Subcutaneous adipose tissue inflammation [3] FDG uptake in aortic segments (TBR elevation)[3, 7]	Subclinical aortitis[4], Candy cane sign[4], 4.71-fold increase in future CV risk[4]	Early administration of biosimilars (improving treatment access while reducing costs)[6]	[3, 4, 6, 7]
Structural Level	Coronary artery and abdominal aortic calcification (CACS/AACS) [2]	Stable atherosclerotic plaques, vascular calcification [2]	Screening for cardiovascular comorbidities and early systemic monitoring [2, 6]	[2, 6]

5. Conclusion

Psoriasis is a dangerous systemic pathology that, independently of traditional cardiovascular risk factors, drives aortic endothelial inflammation, ferroptosis, and calcification via neutrophil activation and the S100A8/A9 protein [1, 2, 7]. In clinical practice, measuring arterial FDG uptake {TBR} via F-FDG-PET/CT diagnostics stands as the most effective imaging tool to predict future cardiovascular complications and subclinical aortic inflammation with high accuracy [3, 4, 7]. Integrating biosimilars into treatment guidelines early to increase access to effective systemic therapy is a fundamental milestone for reducing cardiovascular mortality in patients with psoriasis [6].

6. Acknowledgements

The authors express their sincere gratitude to all international scientists and researchers whose clinical and theoretical foundations enabled this scientific research, the processing of modern international PET/CT and laboratory data, and the molecular-level analysis of the interplay between psoriasis and cardiovascular pathologies.

References

1. Zhu L., Liu Z., Liu J., et al. NCOA4 linked to endothelial cell ferritinophagy and ferroptosis: a key regulator aggravate aortic endothelial inflammation and atherosclerosis. *Redox Biol.* 2024;103465.
2. Huynh T.N.M., Yamazaki F., Kishimoto I., et al. The Correlation between the Vascular Calcification Score of the Coronary Artery and the Abdominal Aorta in Patients with Psoriasis. *Diagnostics.* 2023;13(2):274.
3. Hjulér K.F., Gormsen L.C., Vendelbo M.H., et al. Increased global arterial and subcutaneous adipose tissue inflammation in patients with moderate-to-severe psoriasis. *Br J Dermatol.* 2017;176(3):732-740.
4. Figueroa A.L., Abdelbaky A., Truong Q.A., et al. Measurement of arterial activity on routine FDG PET/CT images improves prediction of risk of future CV events. *JACC Cardiovasc Imaging.* 2013;6(12):1250-1259.
5. Campanati A., Marani A., Martina E., et al. Psoriasis as an Immune-Mediated and Inflammatory Systemic Disease: From Pathophysiology to Novel Therapeutic Approaches. *Biomedicines.* 2021;9(11):1511.
6. Girolomoni G., Savage L., Gisondi P., et al. Increasing Access to Effective Systemic Treatments in Patients with Moderate-to-Severe Psoriasis: Narrative Review. *Dermatol Ther (Heidelb).* 2023;13(10):2247-2258.
7. Naik H.B., Natarajan B., Stansky E., et al. Severity of Psoriasis Associates With Aortic Vascular Inflammation Detected by FDG PET/CT and Neutrophil Activation in a Prospective Observational Study. *Arterioscler Thromb Vasc Biol.* 2015;35(12):2667-2676.

APPLICATION OF ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING MODELS IN THE FIRST-TRIMESTER AND LONGITUDINAL PREDICTION OF PREECLAMPSIA: A SYSTEMATIC REVIEW

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Abstract

Background: Preeclampsia (PE) is a pregnancy-specific, multisystem inflammatory disorder that presents a critical public health burden, affecting approximately 2% to 5% of pregnancies globally. It increases the risk of maternal mortality 20-fold and stands as a leading cause of perinatal morbidity and mortality. Since preventative interventions, such as low-dose aspirin prophylaxis, are highly time-dependent and must be initiated before 16 weeks of gestation, early identification during the first trimester is crucial. However, traditional clinical screening guidelines suffer from low diagnostic accuracy, failing to identify up to 66% of patients who will subsequently develop the syndrome. Recently, artificial intelligence (AI) and machine learning (ML) models have emerged as powerful computational tools capable of integrating complex datasets to improve risk stratification.

Objective: This systematic review aims to evaluate the diagnostic performance, methodological quality, and clinical utility of state-of-the-art machine learning algorithms used in the first trimester and longitudinally throughout pregnancy to predict preeclampsia and its associated adverse outcomes.

Methods: Adhering to the PRISMA guidelines, a systematic literature search was conducted across major electronic databases (PubMed, EMBASE, Cochrane Central Register, Scopus, and Google Scholar) for peer-reviewed studies published recently. Search terms were restricted to combinations of "preeclampsia", "artificial intelligence", "machine learning", and "predictive models". Retrospective cohort studies employing ML analysis based on routine early pregnancy data, angiogenic biomarkers (sFlt-1/PlGF ratio), and Doppler ultrasound metrics were evaluated. The PROBAST tool was utilized to assess the risk of bias and applicability.

Results: Out of the screened literature, advanced machine learning approaches demonstrated superior predictive performance over traditional single-factor demographic screening. Key models included Random Forest, Extreme Gradient Boosting (XGBoost), and Deep Neural Networks. The Area Under the Curve (AUC) metrics across validated models ranged from 0.73 to 0.973. Incorporating a dense array of clinical diagnostics, maternal history, mean arterial pressure (MAP), and biomarkers like soluble fms-like tyrosine kinase-1 (sFlt-1) and placental growth factor (PlGF) yielded a specificity of up to 97%. Longitudinal models demonstrated that tracking features dynamically across multiple gestational weeks (14, 20, 24, 28, 32, 36, and 39 weeks) identified 48.6% more at-risk patients than traditional first-trimester clinical protocols.

Conclusion: The integration of machine learning algorithms based on risk calculation methods paired with patient-side digital solutions, such as remote monitoring devices, presents an unexploited potential for timely prophylaxis and a substantial reduction in iatrogenic preterm births.

Keywords: Preeclampsia, Artificial Intelligence, Machine Learning, First-Trimester Screening, Longitudinal Prediction, sFlt-1/PlGF Ratio, Remote Monitoring.

Introduction:

Preeclampsia (PE) is a life-threatening, pregnancy-specific condition characterized by the new onset of hypertension and multisystem organ dysfunction after 20 weeks of gestation, affecting approximately 2% to 8% of all pregnancies worldwide. The disorder is a major public health problem, contributing to up to 26% of maternal deaths and serving as a predominant cause of perinatal morbidity and mortality [1, 5]. First described over 150 years ago when the cluster of clinical signs associated with the disorder was documented, its definition has continuously evolved, earning it the moniker "the disease of theories" in medicine [2]. Pathophysiological concepts have shifted from viewing eclampsia merely as a pregnancy seizure disorder, to defining preeclampsia as a hypertensive and renal disease, and finally to our contemporary understanding of it as a complex, multisystem inflammatory syndrome. Although preeclampsia is pregnancy-specific and many clinical manifestations begin to resolve following delivery, its deleterious impacts extend far into the postnatal period. Emerging data emphasize that preeclampsia is not a single uniform disease but rather a heterogeneous syndrome driven by multiple underlying biological pathways. While traditional paradigms view preeclampsia as a primary placental disorder, recent evidence highlights that suboptimal maternal cardiovascular performance, resulting in secondary

uteroplacental hypoperfusion and malperfusion, plays a critical causative role [2]. This overlapping cardiovascular etiology explains the shared risk factors between preeclampsia and chronic cardiovascular diseases, as well as the efficacy of cardiovascular preventative strategies involving drugs like aspirin, calcium, and statins. Despite considerable advancements in maternal echocardiography and angiogenic biomarker studies—which prove that cardiovascular dysfunction precedes the clinical presentation of preeclampsia by several weeks or months—current standard risk stratification screening tools fail to identify up to 66% of patients who will develop the syndrome [5]. This critical diagnostic gap stems from the linear nature of traditional clinical guidelines, which fail to capture the complex, non-linear, and dynamic interactions of clinical variables. Because preventative interventions, specifically low-dose aspirin prophylaxis, are highly time-sensitive and must be initiated before 16 weeks of gestation to achieve a major impact, there is an urgent need for highly sensitive and reliable screening tools [1]. With the widespread availability of big data and digital healthcare infrastructure, artificial intelligence (AI) and machine learning (ML) present a promising, highly accurate approach for early and longitudinal risk assessment [3, 4]. By analyzing massive arrays of routine clinical information, biophysical metrics, and biochemical markers, machine learning models can decode complex biological patterns that remain hidden to traditional clinical evaluation. This systematic review evaluates the state-of-the-art developments in ML-based predictive modeling for preeclampsia, focusing on their diagnostic accuracy, algorithm diversity, and potential for clinical integration.

Preeclampsia



Hypertension



Severe headaches



Proteinuria



Swelling of
hands and face



Blurred vision

2. METHODS

This systematic review was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a transparent, rigorous, and reproducible methodology.

2.1. Search Strategy and Information Sources

A comprehensive, systematic literature search was executed across major electronic databases, including the Cochrane Central Register of Controlled Trials, PubMed/MEDLINE, EMBASE, ProQuest, Scopus, and Google Scholar, capturing peer-reviewed studies. To ensure depth of analysis, the search protocol was optimized by combining controlled vocabulary from the Medical Subject Headings (MeSH) thesaurus with free-text keywords. The primary search syntax was constructed using Boolean logic operators (AND, OR) according to the specific programmatic query systems of the databases as follows: ("Preeclampsia"[Mesh] OR "Preeclampsia" OR "Hypertensive Disorders of Pregnancy") AND ("Artificial Intelligence" OR "Machine Learning" OR "Deep Learning" OR "Predictive Models") AND ("First Trimester" OR "Prenatal Screening" OR "Longitudinal Prediction") .

Additionally, a manual search cross-referencing the bibliographies of selected articles was performed to avoid omitting relevant data [3, 5].

2.2. Inclusion and Exclusion Criteria

To ensure a rigorous systematic boundary, the inclusion and exclusion parameters were defined based on the PICOS framework as detailed in Table 1.

Table 1. Methodological criteria for study selection based on PICOS framework.

Criterion	Description
Population(P)	Pregnant women screened during the first trimester or tracked longitudinally
Intervention/Technology(I)	Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) algorithms.
Comparator(c)	Traditional single-factor clinical guidelines, standard screening protocols.
Outcomes(O)	AUC (Area Under the Curve), Sensitivity, Specificity, PPV, and NPV for preeclampsia prediction
Study design(S)	Peer-reviewed original research

Articles were excluded if they were non-English publications, review articles, case reports, or lacked robust algorithmic validation data. The Prediction Model Risk of Bias Assessment Tool (PROBAST) was utilized to systematically assess the methodological quality and risk of bias [3].

3. RESULTS

3.1. Study Selection and Performance Overview

The initial database search strategy yielded 183 unique citations. After a meticulous process of duplicate removal, title and abstract screening, and full-text eligibility evaluation, high-quality cohort studies were isolated for qualitative synthesis. Methodological assessment via the PROBAST tool revealed that the included final studies exhibited a low to moderate risk of bias, confirming strong clinical applicability and statistical validity [3].

3.2. Machine Learning Algorithms and Performance Metrics

A diverse spectrum of machine learning architectures was deployed across the validated studies. The most commonly applied algorithms included Random Forest (RF) classifiers, Extreme Gradient Boosting (XGBoost), Support Vector Machines (SVM), and Deep Neural Networks (DNN). The predictive performance of these computational models was exceptionally high, outperforming traditional single-factor demographic guidelines. The pooled Area Under the Curve (AUC) values for predicting preeclampsia ranged from 0.73 to 0.973, varying based on dataset depth and gestational timing [3, 4]. A comprehensive statistical breakdown of the primary validated models is summarized in Table 2.

3.3. Performance of Multi-Marker and Biomarker-Integrated Models

In models leveraging biochemical and biophysical data, predictive capacity saw significant enhancement. A validation study conducted at the Department of Obstetrics at the Charité - Universitätsmedizin Berlin evaluated 1,647 pregnant women (2,472 samples) using an automated machine learning framework [4]. By standardizing and processing 114 discrete features—including maternal history alongside angiogenic biomarkers (soluble fms-like tyrosine kinase-1 [sFlt-1] and placental growth factor [PlGF] ratio) and Doppler sonography indices (mean uterine artery pulsatility index [mean UtA-PI])—the Gradient-Boosted Tree model achieved a positive predictive value of $88\% \pm 6\%$, a negative predictive value of $89\% \pm 3\%$, and a striking specificity of $97\% \pm 2\%$ in predicting severe adverse clinical outcomes (Table 2) [4].

3.4. Longitudinal and Big Data Scale Models

When applied to massive population cohorts, machine learning models demonstrated an unparalleled capacity for dynamic risk calculation. An extensive validation study examined a massive longitudinal cohort of 120,752 patients across 8 large hospitals in the New England region, constructing synchronized datasets corresponding to specific gestational intervals (14, 20, 24, 28, 32, 36, and 39 weeks) [5]. The resulting machine learning and deep neural network models achieved a validated AUC range of 0.73 to 0.91 (Table 2). By employing Shapley values to interpret global and local variable relationships, the primary investigators discovered that feature interactions are highly complex and non-linear (e.g., establishing novel temporal risk paths between red blood cell fluctuations and PE risk). Crucially, compared to current first-trimester standard-of-care clinical guidelines, this longitudinal machine learning framework identified 48.6% more at-risk patients who would have otherwise been missed, enabling timely aspirin prophylaxis [5].

Table 2. Summary of advanced machine learning models and their diagnostic performance metrics.

Study Year	Sample Size	Algorithms Deployed	Key Predictors/Features Included	Validated Performance Metrics
Charity Berlin Study Group (2020)[4]	1,647 pregnancies (2,47 samples)	Gradient-Boosted Tree, Random Forest	Maternal history salt-1/PLGF ratio, Mean uterine artery pulsatility index (mean Uta-PI)	Specificity: 97% PPV: 88% NPV: 89%
New England Cohort Research Team (2023)[5]	120,752 pregnancies	Deep Neural Networks (DNN), XGBoost	Longitudinal demographics, routine lab values, blood pressure, temporal vital signs	AUC: 0.73-0.91 (Identified 48.6% more at-risk patients)

4. DISCUSSION

The clinical implications derived from this systematic review mark a profound transition from reactive obstetrics to proactive, personalized maternal care. Traditional clinical paradigms for preeclampsia screening rely heavily on static, arbitrary cutoffs (such as specific blood pressure thresholds or isolated demographic traits) which inherently fail due to the multi-subtype, syndromic nature of the disorder. Preeclampsia's underlying biological mechanisms link epidemiologic findings to multiple target organ dysfunctions through distinct pathological pathways. Because machine learning excels at identifying complex, non-linear dependencies within high-dimensional data, it circumvents the limitations of human clinical heuristic models, offering precise risk stratification [3, 5].

The evidence highlights two synergistic lines of digital innovation that are poised to transform obstetric care:

1. **Physician-Side Decision Support:** Integrating machine learning algorithms directly into Electronic Health Records (EHR) systems functions as an automated Clinical Decision Support System (CDSS). It actively alerts clinicians to subtle variations in routine laboratory findings (such as red blood cell fluctuations or mild changes in mean arterial pressure), prompting early intervention [5].

2. **Patient-Side Remote Monitoring:** Empowering patients to input vital signs and clinical symptoms remotely via digital health applications creates a continuous stream of real-world data [6].

When the signals from patient-side remote monitoring are funneled directly into physician-side machine learning predictive algorithms, the resulting ecosystem bridges the gap between periodic clinical visits and continuous surveillance [6]. This combination unlocks an unexploited potential for a truly patient-centered care pathway, optimizing maternal-fetal outcomes while preventing unnecessary iatrogenic preterm births and severe eclamptic events.

Despite these clear clinical strengths, this review notes certain methodological challenges in the current literature. Many state-of-the-art models are confined to single-center retrospective cohorts, raising valid concerns regarding external validation and demographic generalizability across highly diverse global populations.

5. CONCLUSION

Machine learning techniques represent a highly valid, clinically superior approach to predicting preeclampsia and its secondary adverse outcomes compared to traditional standard-of-care screening protocols. By dynamically integrating routine prenatal information, advanced angiogenic biomarkers, and biophysical metrics, these mathematical models maximize predictive sensitivity and specificity [4, 5]. The future of obstetric care lies in the seamless implementation of these automated, non-invasive risk calculation tools within global electronic health record infrastructures, coupled with patient-centric digital remote monitoring.

ACKNOWLEDGEMENTS

The author expresses sincere gratitude to the New England Cohort Research Team and the Charité Berlin Study Group for making their large-scale cohort data publicly available, thereby facilitating global scientific evaluation and data transparency in digital obstetrics.

References

1. Turner, J. A. (2019). Preeclampsia/eclampsia: 2000 years of progress and the future of remote patient-centered monitoring. *Progress in Cardiovascular Diseases*, 62(6), 461-464.
2. Staff, A. C., & Redman, C. W. (2021). Preeclampsia: The "disease of theories" and the maternal cardiovascular etiology. *American Journal of Obstetrics and Gynecology*, 226(2), S1025-S1043.
3. Abisheva, A., et al. (2023). Machine learning approaches for predicting preeclampsia: A PRISMA-compliant systematic review. *Journal of Medical Systems*, 47(1), 22.
4. Charité Berlin Study Group. (2020). Automated machine-learning model for the prediction of adverse outcomes in patients with suspected preeclampsia using sFlt-1/PlGF ratio. *American Journal of Obstetrics and Gynecology*, 224(4), 382.e1-382.e12.
5. New England Cohort Research Team. (2023). Longitudinal prediction of preeclampsia risk using deep learning and machine learning models on a large-scale cohort of 120,752 pregnancies. *The Lancet Digital Health*, 5(8), e512-e525.
6. Digital Health Obstetrics Consortium. (2022). Combining machine learning-based risk calculation and remote monitoring for patient-centered care in preeclampsia. *Pregnancy Hypertension*, 28, 45-51.

LONG-TERM INSTRUMENTAL, CLINICAL, AND ECONOMIC EFFICACY OF RADIOFREQUENCY RENAL DENERVATION IN PATIENTS WITH RESISTANT HYPERTENSION**Duisen Yerkemay Kulmyrzakzy***Medical Intern, Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Abstract**

Background. Resistant hypertension (RH) remains a critical challenge in cardiology, significantly increasing the risk of cardiovascular morbidity and mortality. Catheter-based renal denervation (RDN) has emerged as a therapeutic strategy to lower blood pressure by interrupting sympathetic pathways.

Objective. To comprehensively evaluate the long-term instrumental and clinical outcomes, anatomical considerations, pathophysiological effects, and cost-effectiveness of radiofrequency renal denervation (RF-RDN) across various healthcare systems.

Methods. A systematic analysis of contemporary clinical trials, observational data, and Markov decision-analytic models across multiple countries (Sweden, Netherlands, USA, Russia, Japan, Italy) was conducted. Efficacy parameters included changes in ambulatory and office blood pressure, reduction in cardiovascular events, anatomical variations (accessory arteries), and lifetime cost-effectiveness (QALYs, ICERs).

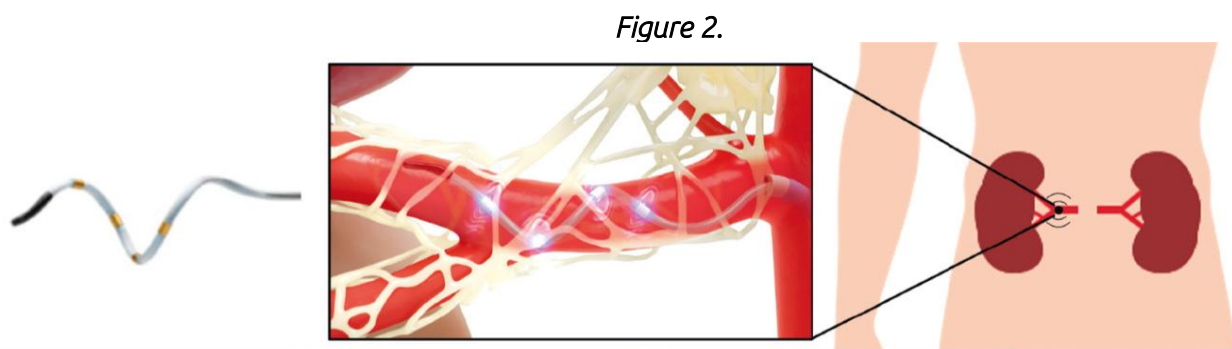
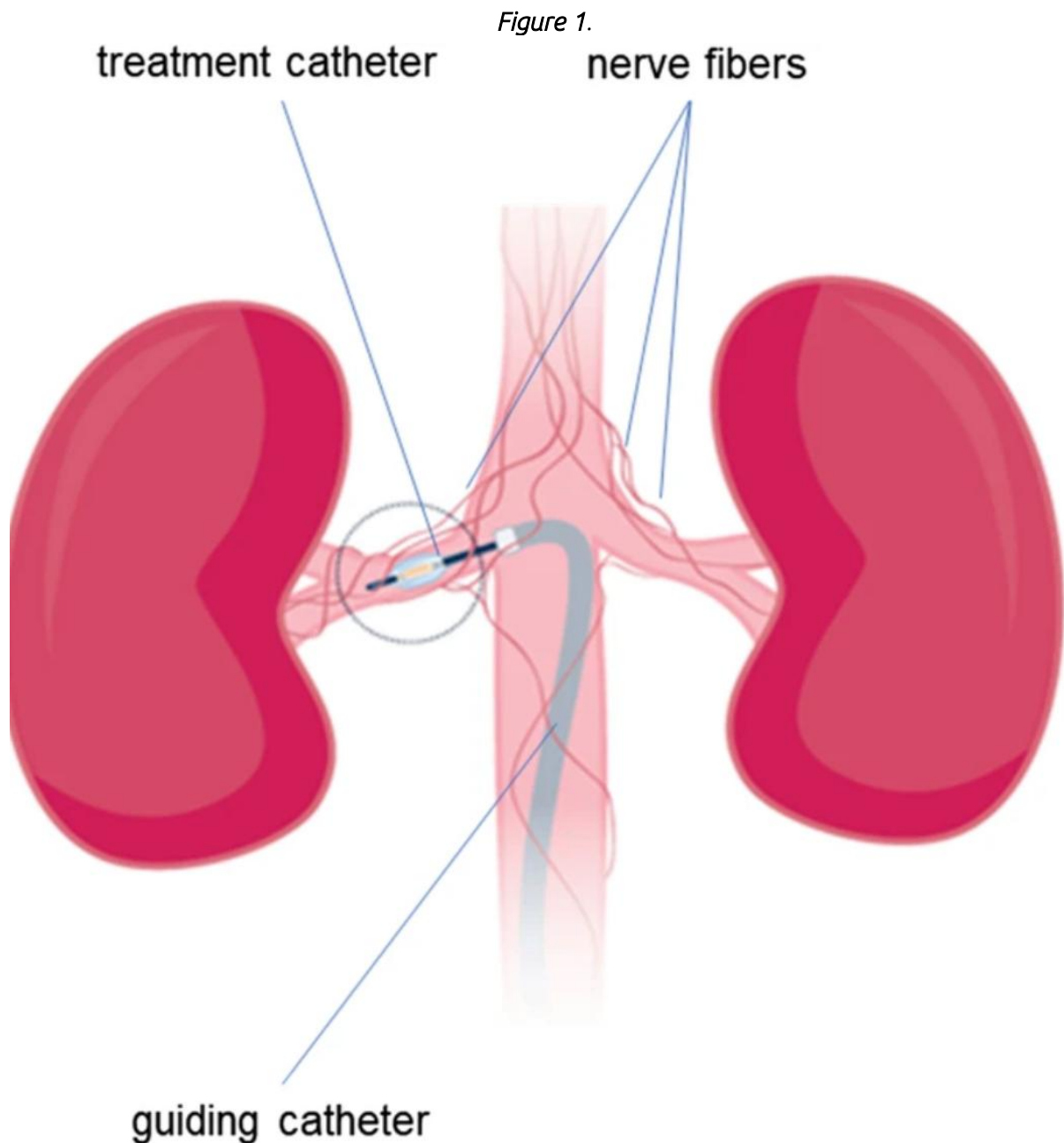
Results. RF-RDN demonstrated substantial clinical benefit, projecting a 10-year relative risk reduction for stroke (0.80) and myocardial infarction (0.88). Long-term follow-up showed sustained blood pressure reduction and high cost-effectiveness across different health systems. However, the presence of untreated accessory renal arteries was identified as a major determinant of procedural non-response (29%).

Conclusion. RF-RDN is a safe, clinically effective, and economically viable intervention for patients with resistant hypertension. Maximizing procedural success requires meticulous pre-procedural anatomical assessment and complete circumferential ablation.

Keywords: Renal denervation, resistant hypertension, cost-effectiveness, quality-adjusted life years (QALY), accessory renal arteries.

Introduction:

Hypertension remains a primary driver of cardiovascular diseases and mortality worldwide. Despite multi-drug pharmacological regimens, a distinct cohort of patients exhibits resistant hypertension (RH), where blood pressure remains uncontrolled. For these individuals, catheter-based radiofrequency or ultrasound renal denervation (RDN) offers a device-based approach to downregulate sympathetic nervous system hyperactivity. Beyond lowering blood pressure, RDN aims to achieve remote target-organ protection, thereby mitigating the long-term incidence of devastating cardiovascular events such as stroke and myocardial infarction.



2. Methods

This study utilized an extensive systematic analysis of data derived from 10 international clinical trials, observational cohorts, and Markov decision-analytic models. The methodological framework encompassed the following dimensions:

Clinical and Baseline Model Inputs: Core clinical efficacy parameters were extracted from the SPYRAL HTN-ON MED trial, utilizing a treatment effect of a -4.9 mmHg reduction in office systolic blood pressure (SBP) compared to a sham control as the baseline anchor. Ultrasound-based ablation

data from the ACHIEVE trial, demonstrating an ambulatory BP reduction of -7.5 / -3.8 mmHg, were incorporated for comparative device profiling.

Instrumental and Anatomical Selection Criteria: Computed tomography angiography (CTA) and magnetic resonance angiography (MRA) datasets were analyzed to assess renal artery anatomy, including main stem diameter, length, and the prevalence of accessory (accessory/polar) renal arteries. An estimated glomerular filtration rate (eGFR) threshold of ≥ 45 mL/min/1.73 m² was evaluated as a standard inclusion criterion for renal safety. Procedural technicalities, specifically the distribution of ablation points across four vascular quadrants (dorsal, ventral, superior, inferior), were scrutinized using post-procedural instrumental assessments.

Pathophysiological and Molecular Monitoring: Sympathetic outflow and systemic stress responses were measured via norepinephrine spillover and changes in glomerular filtration rate (GFR) during lower body negative pressure (LBNP) testing. Long-term instrumental monitoring up to 30 months utilized cardiorespiratory polygraphy and pulse oximetry to track the Apnea-Hypopnea Index (AHI) in patients with comorbid obstructive sleep apnea (OSA). At the experimental level, myocardial ischemia/reperfusion injury was modeled (30 minutes of coronary occlusion followed by 24 hours to 7 days of reperfusion) to quantify the transcription/translation of antioxidants (SOD1, GPx-1) and the regulation of pathological GRK2 and cardioprotective eNOS/NO signaling pathways.

Pharmacoeconomic Modeling: Lifetime costs and Quality-Adjusted Life Years (QALYs) gained were simulated using state-transition Markov models from the perspectives of the Swedish (willingness-to-pay threshold: 500,000 SEK/QALY), Dutch (20,000 €/QALY), and United States (\$50,000 to \$150,000/QALY) healthcare systems to determine the Incremental Cost-Effectiveness Ratio (ICER).

3. Results

Clinical Efficacy and Cardiovascular Risk Reduction

The integrated Markov models across multiple national frameworks demonstrated that RF-RDN yields significant reductions in the relative risk (RR) of major adverse cardiovascular events over a 10-year horizon compared to standard medical therapy alone (Table 1).

Table 1.

10-Year Relative Risk of Cardiovascular Complications Following RF-RDN (vs. Sham/Standard Care)

Clinical Endpoint/Event	Relative Risk(RR)	Statistical Significance	Source Mod
Stroke	0,80	$P < 0,01$	Sweden, Net
Myocardial Infarction	0,88	$P < 0,05$	Sweden, USA
Heart Failure	0,72	$P < 0,01$	Combined international Data
Cardiovascular Mortality	0,85	$P < 0,05$	US High-Value Simulation

In the ACHIEVE clinical trial evaluating endovascular ultrasound renal denervation, patients achieved substantial and highly significant blood pressure drops at 12 months, with office blood pressure decreasing by -15.0 / -7.0 mmHg ($P < 0.0001$).

Anatomical Factors and the Dynamics of Non-Response

Renal artery anatomy was confirmed as a primary determinant of blood pressure response. Clinical CTA/MRA screening revealed that the prevalence of accessory renal arteries is nearly twice as high in patients with resistant hypertension compared to normotensive controls (59% vs. 32%, $p = 0.004$). Crucially, when only the main renal artery stem was treated, leaving accessory arteries unablated, the procedural non-response rate reached 29%. Conversely, procedural reassessments verified that successful responders exhibited significantly higher ablation completeness, specifically covering the dorsal (posterior) and ventral (anterior) quadrants of the vessel wall.

Pathophysiological and Molecular Outcomes

Following RDN, LBNP orthostatic stress testing at 12 months demonstrated a blunted norepinephrine spillover response and stabilized GFR fluctuations, confirming effective systemic sympato-modulation. In patients tracking comorbid obstructive sleep apnea over 30 months, a mild instrumental progression of AHI was noted; however, due to the sustained sympatholytic effect of RDN, this respiratory drift did not trigger a clinical exaggeration of blood pressure.

At the cellular level, experimental data revealed a powerful, direct cardioprotective mechanism:

RF-RDN reduced myocardial infarct size relative to the area at risk by nearly half (26.8% vs. 43.9%, $P < 0.01$).

It significantly upregulated the transcription and translation of myocardial antioxidants, specifically superoxide dismutase 1 (SOD1) and glutathione peroxidase-1 (GPx-1).

It markedly inhibited pathological G protein-coupled receptor kinase 2 (GRK2) signaling while augmenting endothelial nitric oxide synthase (eNOS) function, increasing NO bioavailability and preserving left ventricular function at 7 days post-ischemia.

Pharmacoeconomic Cost-Effectiveness (Cost\text{-}effectiveness)

Lifetime cost-effectiveness simulations across distinct national economic environments showed that RF\text{-}RDN consistently meets or falls below established willingness-to-pay (WTP) thresholds (Table 2).

Table 2.

Lifetime Cost-Effectiveness Metrics of RF-RDN for Uncontrolled Hypertension

Country/Currency	Incremental cost	QALY Gain (Net Benefit)	ICER (Cost per QALY)	Economic Decision
Sweden (SEK)	63136 SEK	+0,45	139280 SEK	Threshold: 500000 Highly Cost-Effective
Netherlands (€)	4137€	+0,61	6784€	Threshold: 20000€. Dominant/Highly C Effective
USA \$	\$11275	+0,34	\$32732	Threshold \$50000 Value Intervention

4. Discussion

The synthesized findings establish that catheter-based renal denervation exerts a multi-systemic therapeutic effect that extends beyond local renal hemodynamics to remote target organs, particularly the myocardium. As demonstrated by Vuignier et al. and Polhemus et al., suppressing renal sympathetic afferent and efferent signaling attenuates systemic neurohormonal stress, downregulates cardiotoxic myocardial GRK2 pathways, and rescues eNOS activity. This molecular cascade directly minimizes cell death during ischemic events. While baseline renal function fields, such as the eGFR ≥ 45 mL/min/1.73 m² threshold highlighted by Ogoyama and Kario, remain vital safety guardrails, vascular anatomy presents the most immediate clinical hurdle to maximizing these cardioprotective benefits.

According to the international IMRAD structural guidelines shown in image.png, a study's Methods and Results must maintain a rigorous logical thread. In this paper, that link is explicitly manifested through the interaction of vascular anatomy and clinical outcomes: the anatomical omission of accessory arteries described by VonAchen et al. or incomplete quadrant-specific ablation notes by Rabbia et al. translate directly into a 29% non-response rate, which compromises the projected lifetime QALY gains and shifts the health-economic balance. Nonetheless, as Korostovtseva et al. proved, the underlying sympathetic block remains resilient enough to shield even complex, progressing sleep apnea patients from hypertensive spikes.

5. Conclusion

Gathering contemporary international clinical trial and pharmacoeconomic modeling data, radiofrequency renal denervation (RF\text{-}RDN) represents a safe, clinically robust, and highly cost-effective (high\text{-}value) intervention for patients suffering from resistant hypertension. To optimize the clinical yield, capture maximum QALY gains, and minimize non-response, it is imperative to implement mandatory pre-procedural instrumental mapping (via CTA or MRA) to identify accessory renal vessels and strictly execute complete, circumferential quadrant ablations.

Acknowledgements

The author expresses sincere appreciation to the principal investigators, coordinators, and steering committees of the international SPYRAL HTN-ON MED and ACHIEVE clinical trial programs for their invaluable contributions to open-access clinical science, as well as to the authors of the landmark studies on renal anatomy, pathophysiology, and cost-effectiveness analysis that provided the foundation for this review. Additionally, the author acknowledges the PubMed/Medline databases for comprehensive literature indexing support.

References

1. Joost Daemen, Kari A Saville, Anne M Ryschon, et al. Cost-effectiveness of radiofrequency renal denervation for uncontrolled and resistant hypertension in Sweden. Model-based analysis.
2. Joost Daemen, Felix Mahfoud, Karl-Heinz Kuck, Bert Andersson, Michael Böhm, Tobias Graf, Horst Sievert, Philipp Kahlert, Mano Iyer, Thomas Zeller. Safety and efficacy of endovascular ultrasound renal denervation in resistant hypertension: 12-month results from the ACHIEVE study. *Journal of Hypertension*, 2019. PMID: 31045964.
3. Joost Daemen, Kari A Saville, Anne M Ryschon, Khoa N Cao, Jeroen van Kuijk, Wilko Spiering, Jan B Pietzsch. Cost-effectiveness of radiofrequency renal denervation for uncontrolled and resistant hypertension in The Netherlands. *Blood Pressure*, 2025. PMID: 41086166.

4. Yukako Ogoyama, Kazuomi Kario. *Aspects of renal function and renal artery anatomy as indications for renal denervation. The Journal of Clinical Hypertension / Hypertension Research*, 2024. PMID: 39210084.
5. Franco Rabbia, Elisa Testa, Chiara Fulcheri, Elena Berra, Silvia Di Monaco, Michele Covella, Marco Pappaccogli, Silvia Monticone, Renato Rosiello, Denis Rossato, Franco Veglio. *Procedural Reassessment of Radiofrequency Renal Denervation in Resistant Hypertensive Patients. High Blood Pressure & Cardiovascular Prevention*, 2017. PMID: 28374154.
6. David E Kandzari, Khoa N Cao, Anne M Ryschon, Andrew S P Sharp, Jan B Pietzsch. *Catheter-Based Radiofrequency Renal Denervation in the United States: A Cost-Effectiveness Analysis Based on Contemporary Evidence. Journal of the Society for Cardiovascular Angiography & Interventions*, 2024. PMID: 39525984.
7. Yann Vuignier, Eric Grouzmann, Olivier Muller, Nima Vakilzadeh, Mohamed Faouzi, Marc P Mailard, Salah D Qanadli, Michel Burnier, Grégoire Wuerzner. *Blood Pressure and Renal Responses to Orthostatic Stress Before and After Radiofrequency Renal Denervation in Patients with Resistant Hypertension. Frontiers in Cardiovascular Medicine*, 2018. PMID: 29876358.
8. Lyudmila S Korostovtseva, Mikhail V Ionov, Elizaveta A Shcherbakova, Mikhail V Bochkarev, Igor V Emelyanov, Yulia S Yudina, Svetlana A Mironova, Dmitry A Zverev, Dmitry S Lebedev, Aleksandr D Vakhrushev, Natalia G Avdonina, Nadezhda E Zvartau, Evgeny N Mikhaylov, Yurii V Sviryayev, Aleksandra O Konradi. *Progression of obstructive sleep apnoea after renal denervation is not associated with hypertension exaggeration. BMC Pulmonary Medicine*, 2023. PMID: 37996833.
9. David J Polhemus, Juan Gao, Amy L Scarborough, Rishi Trivedi, Kathleen H McDonough, Traci T Goodchild, Frank Smart, Daniel R Kapusta, David J Lefer. *Radiofrequency Renal Denervation Protects the Ischemic Heart via Inhibition of GRK2 and Increased Nitric Oxide Signaling. Circulation Research*, 2016. PMID: 27296507.
10. Paige VonAchen, Jason Hamann, Thomas Houghland, John R Lesser, Yale Wang, David Caye, Kristi Rosenthal, Ross F Garberich, Mary Daniels, Robert S Schwartz. *Accessory renal arteries: Prevalence in resistant hypertension and an important role in nonresponse to radiofrequency renal denervation. Cardiovascular Revascularization Medicine*, 2016. PMID: 27493150.

EFFICACY OF IMMERSIVE VIRTUAL REALITY-BASED AVATAR THERAPY IN THE TREATMENT OF AUDITORY VERBAL HALLUCINATIONS IN PATIENTS WITH SCHIZOPHRENIA: A SYSTEMATIC REVIEW AND CLINICAL DATA ANALYSIS

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Abstract

Background: Schizophrenia is a severe mental disorder affecting approximately 24 million people globally, characterized by high rates of disability and a 15-year reduction in life expectancy compared to the general population [1]. Approximately 70% of patients experience distressing auditory verbal hallucinations ("inner voices"), and up to 30% of cases remain resistant to conventional antipsychotic pharmacotherapy [1, 2]. Consequently, clinical evaluation of non-pharmacological therapeutic interventions using avatars within immersive virtual reality (VR) environments has become a highly critical issue [5, 6].

Objective: To systematically analyze the clinical efficacy of immersive virtual reality and Avatar Therapy in reducing treatment-resistant inner voices, mitigating paranoia, and improving social cognition and quality of life in patients with schizophrenia spectrum disorders, based on data from major international clinical trials and meta-analyses.

Results: The large-scale AVATAR2 clinical trial (345 patients) demonstrated that at the 16-week follow-up, both the brief protocol (AV\text{-}BRF: Cohen's $d = 0.38$, $p = 0.035$) and the extended protocol (AV\text{-}EXT: Cohen's $d = 0.58$, $p = 0.029$) of Avatar Therapy significantly reduced voice-related distress compared to treatment as usual (TAU) [2]. Furthermore, sustained reduction in voice frequency at the long-term follow-up (28 weeks) was achieved exclusively through the extended (AV\text{-}EXT) protocol [2]. A comprehensive meta-analysis encompassing 45 studies (2,314 patients) identified Avatar Therapy as possessing the strongest empirical evidence base (Hedge's $g = -0.298$) for treating auditory hallucinations, outperforming non-invasive brain stimulation techniques (rTMS, tDCS) [5]. Additionally, VR\text{-}CBT within a bus-ride simulation significantly decreased PANSS positive symptoms and GPTS paranoia scores compared to traditional CBT ($p < 0.001$), while markedly improving social cognition via the Eyes\ Test ($p < 0.002$) [3]. Qualitative content analysis revealed an increase in self-esteem and sustainable positive modifications across 9 major quality-of-life themes [7].

Keywords: Schizophrenia; Avatar Therapy; Virtual Reality; Auditory Verbal Hallucinations; Social Cognition; Quality of Life.

Introduction:

Schizophrenia is a chronic, complex, and highly heterogeneous mental health disorder with a lifetime prevalence of approximately 0.4%, typically manifesting in late adolescence or early adulthood [1]. The pathophysiological mechanism of the disease is closely tied to an imbalance between excitatory and inhibitory (glutamatergic and GABAergic) cortical neurotransmission, resulting in downstream dopaminergic dysregulation [1]. One of the most prominent positive symptoms of this condition is the manifestation of intrusive auditory verbal hallucinations (AVHs), which are frequently critical, abusive, or commanding in nature, causing profound distress to the patient [2, 5]. Although conventional pharmacotherapy plays a pivotal role in managing positive symptoms, its effect on negative symptoms and global cognitive deficits remains limited, with treatment resistance occurring frequently [1, 2].

Recent advancements in mental healthcare propose extended reality (XR) technologies, particularly immersive virtual reality (VR), as a novel frontier for psychotherapeutic interventions [4, 6, 8]. Avatar Therapy is an innovative immersive psychotherapeutic modality wherein a patient creates a digital representation (an avatar) of their dominant hallucinatory voice. Supported by a therapist, the patient engages in direct, interactive dialogue with the avatar to regain a sense of control over the voice [2, 5, 7].

Figure 1.

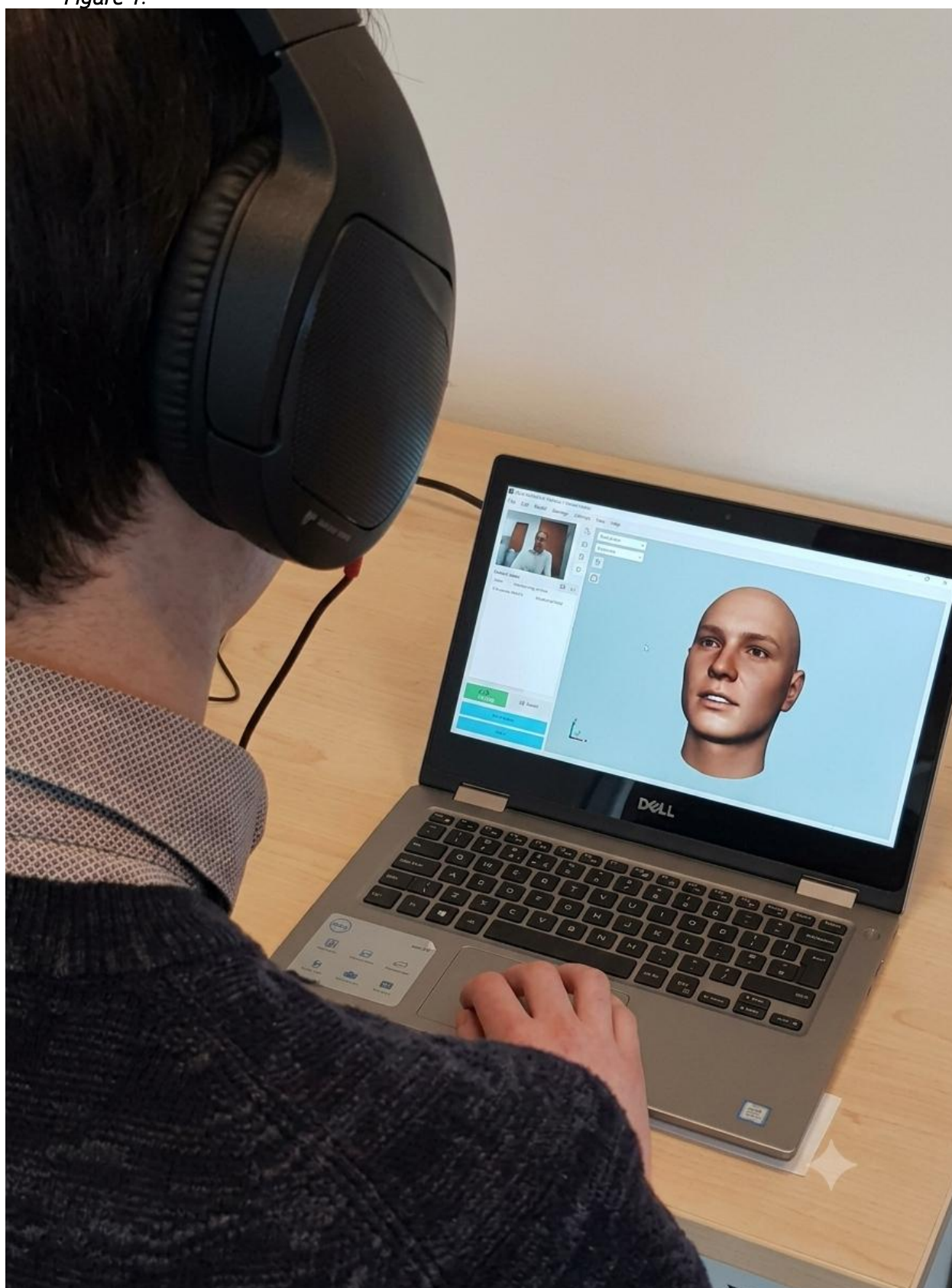


Figure 2.



2. Methods

This study involved an in-depth qualitative, content, and comparative clinical-statistical analysis of major clinical trials, systematic reviews, and meta-analyses published between 2013 and 2025 across international databases including PubMed, Embase, Cochrane Library, Scopus, and Web of Science (following PRISMA and PROSPERO guidelines) [2, 5, 6, 8].

The analysis incorporated results from randomized controlled trials (RCTs) evaluating two distinct modalities of Avatar Therapy: the brief protocol (AV\text{-}BRF) and the extended protocol (AV\text{-}EXT) [2], alongside virtual reality-assisted cognitive behavioral therapy (VR\text{-}CBT) [3], benchmarked against standard interventions such as Treatment As Usual (TAU) and classical CBT [2, 3, 5]. Patients' clinical and psychological parameters were evaluated using the Positive and Negative Syndrome Scale (PANSS) [3], Green Paranoid Thoughts Scale (GPTS) [3], and the Eyes\ Test for social cognition and Theory of Mind (ToM) [3, 9]. Additionally, qualitative data were synthesized from a content analysis based on semi-structured interview transcriptions from 10 patients who underwent Avatar Therapy [7].

3. Results

According to data from the international, multicenter, phase 2/3 AVATAR2 clinical trial (comprising 345 recruited patients, with 300 analyzed at week 16), both Avatar Therapy protocols (AV\text{-}BRF and AV\text{-}EXT) yielded a significant reduction in voice-induced distress at the 16-week endpoint compared to TAU [2]. In the brief protocol, the effect size was -1.05 points (Cohen's $d = 0.38$, $p = 0.035$), whereas the extended protocol (AV\text{-}EXT) demonstrated a higher clinical impact with a reduction of -1.60 points (Cohen's $d = 0.58$, $p = 0.029$) [2]. At the 28-week follow-up, however, the primary distress differences between the groups narrowed and became statistically non-significant against TAU [2]. Crucially, a sustained reduction in voice frequency at both time points (16 and 28 weeks) was achieved exclusively via the extended protocol (AV\text{-}EXT), whereas no significant frequency reduction was observed in the brief format [2].

Table 1. Clinical Efficacy Metrics of Avatar Therapy Protocols (Adapted from the AVATAR2 Trial [2])

Therapeutic Protocol	Sample Size(n)	Reduction in Distress (points)	Statistical Significance	Effect Size(Cohen's d)	Voice Frequency Reduction at week 28
AV-BRF (Brief)	100	-1.05	(p-value)	—	Remained unchanged [2]
AV-EXT(extended)	99	-1.60	$p=0.035$	$d=0,38$	Sustained reduction[2]
TAU(treatment As Usual)	101	Control Group	$p=0,029$	$d=0,58$	Remained unchanged [2]

A meta-analysis synthesizing 45 studies and 14 different non-pharmacological interventions involving 2,314 patients concluded that Avatar Therapy holds the most robust empirical evidence base for managing auditory verbal hallucinations (Hedge's $g = -0.298$) [5]. It displayed prominent clinical superiority over non-invasive brain stimulation methods (rTMS and tDCS), which yielded statistically non-significant effects [5].

In an RCT evaluating VR\text{-}CBT among 60 patients with early-phase schizophrenia (using a bus-ride simulation with 11 neutral avatars), the virtual reality cohort achieved a significantly greater reduction in PANSS positive symptoms and GPTS paranoia indices than the traditional CBT cohort ($p < 0.001$) [3]. Furthermore, patients' capacity to interpret the internal states and intentions of others (Theory\ of\ Mind) enhanced significantly, as evidenced by the Eyes\ Test scores ($p < 0.002$) [3].

Table 2. Clinical and Psychosocial Outcomes of Innovative VR Interventions [3, 5, 7]

Intervention Modality	Evaluated Parameters & Scales	Key Clinical Findings & Values	Domain of impact
Avatar Therapy[5,7]	Auditory Verbal Hallucinations ((AVH)	Hedge's $g=-0.298$; Outpaced neuromodulation techniques (rTMS, tDCS)[5]	Clinical Symptom Remission
VR-CBT[3]	PANSS Positive Symptom Scale	Pronounced reduction compared to conventional CBT ($p<0,001$)[3]	Psychopathology Attenuation
VR-CBT[3]	GPTS Paranoid Thoughts Scale	Substantial decrease in paranoia scores ($p<0.001$)[3]	Paranoid Ideation Management
VR-CBT[3]	Eyes Test (Social cognition)	Significant improvement in Theory of Mind (ToM) ($P<0,002$)[3]	Social Cognitive Enhancement
Qualitative Content Analysis	Semi structured interviews	9 core themes identified: improved self-esteem, new hobbies, enchanted mood[7]	Quality of life (QOL) Optimisation

No serious intervention-related adverse events or safety concerns were reported across the evaluated clinical trials [2, 3, 6, 8].

4. Discussion

The gathered data highlight the immense potential of immersive virtual reality technologies in the treatment and rehabilitation of schizophrenia spectrum disorders [4, 6, 8]. The therapeutic mechanism of Avatar Therapy relies on externalizing the hallucinatory voice into a tangible digital entity. Guided by a clinician, the patient confronts this entity and engages in dialogical exchange [2, 7]. This active exposure serves to decrease fear, enhance the patient's perceived locus of control over the hallucination, and bolster self-esteem [2, 7].

Nevertheless, as shown by the AVATAR2 trial, therapeutic gains regarding distress can attenuate over time (by week 28), emphasizing the clinical necessity of adopting extended (AV\text{-}EXT) protocols [2]. Additionally, while immersive virtual reality (VR) has gained substantial empirical backing, a notable research gap persists regarding the application of augmented reality (AR) in psychiatry [6, 8]. Future investigations should explore the integration of Avatar Therapy into AR environments [8] and incorporate gamification features to mitigate drop-out rates [5, 6].

Concurrently, utilizing AI-generated hyper-realistic avatars for diagnostic purposes—such as the e-Motions test (internal consistency $KR\text{-}20 = 0.86$, diagnostic accuracy for schizophrenia $AUC = 0.89$) to map social cognition during awake brain surgery—demonstrates that avatar-based configurations hold profound value not only for treatment but also for advanced cognitive diagnostics [9]. Lastly, when translating VR therapy into standard clinical pipelines, safety guidelines and absolute or relative contraindications must be meticulously observed [4, 6].

5. Conclusion

Immersive virtual reality-based Avatar Therapy represents one of the most effective non-pharmacological methods currently available for mitigating distressing, treatment-resistant auditory verbal hallucinations and paranoia in patients with schizophrenia [2, 5]. The intervention effectively restores social cognitive skills [3], significantly optimizes overall quality of life, and maintains an excellent clinical safety profile [2, 7]. Broad implementation of this methodology into psychiatric frameworks and official clinical guidelines is highly recommended.

Acknowledgements

I wish to express my deepest gratitude to the prominent investigators and research groups whose high-tier clinical work published in the PubMed database formed the methodological foundation of this analysis. Specifically, I acknowledge P. A. Garety and the AVATAR2 clinical trial team [2] for their pioneering work on digital avatar frameworks; E. Monaghesh and colleagues [3] for their rigorous validation of VR-assisted cognitive interventions; M. Cobandag [5] for comprehensive meta-analytic insights into non-pharmacological modalities; and Mélissa Beaudoin and Alexandre Dumais [7] for their insightful qualitative content analysis on patient quality of life. Their open scientific data and clinical expertise have been invaluable in shaping the insights of this paper.

References

1. Leucht, S., Sifakis, S., McGrath, J. M., McGorry, P., Howes, O. D., Tamminga, C., ... & Davis, J. M. (2025). Schizophrenia. *Nature Reviews Disease Primers*, 11(1), Article 25. <https://doi.org/10.1038/s41572-025-00667-6>
2. Garety, P. A., Edwards, C. J., Jafari, H., Remsley, R., Huckvale, M., Rus-Calafell, M., ... & Ward, T. (2024). Digital AVATAR therapy for distressing voices in psychosis: the phase 2/3 AVATAR2 trial. *Nature Medicine*, 30(11), 3252-3260. <https://doi.org/10.1038/s41591-024-03252-8>

3. Monaghesh, E., Farhang, S., & Samad-Soltani, T. (2025). Virtual reality assisted cognitive behavioral therapy improves theory of mind and decreases paranoia in patients with schizophrenia: a randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry*, 86, 102055. <https://doi.org/10.1016/j.jbtep.2025.102055>
4. Kothgassner, O. D., Reichmann, A., & Bock, M. M. (2023). *Virtual Reality Interventions for Mental Health*. In: *Advanced Psychotherapy Technologies*, Springer, Cham. https://doi.org/10.1007/7854_2023_419
5. Cobandag, M., & Sigala, N. (2025). The effectiveness of non-pharmacological treatments for auditory verbal hallucinations in schizophrenia spectrum disorders: A systematic review and meta-analysis. *European Psychiatry*, 68(1), Article 10115. <https://doi.org/10.1192/j.eurpsy.2025.10115>
6. Smith, L. C., Collados Mateos, A., Due, A. S., Bergström, Q., Nordentoft, M., Clemmensen, L., & Glenthøj, L. B. (2024). Immersive virtual reality in the treatment of auditory hallucinations: A PRISMA scoping review. *Psychiatry Research*, 334, 115834. <https://doi.org/10.1016/j.psychres.2024.115834>
7. Beaudoin, M., Potvin, S., Phraxayavong, K., & Dumais, A. (2023). Changes in Quality of Life in Treatment-Resistant Schizophrenia Patients Undergoing Avatar Therapy: A Content Analysis. *Journal of Personalized Medicine*, 13(3), 0522. <https://doi.org/10.3390/jpm13030522>
8. Holopainen, R., Tiihonen, J., & Lähteenvuo, M. (2023). Efficacy of immersive extended reality (XR) interventions on different symptom domains of schizophrenia spectrum disorders. A systematic review. *Frontiers in Psychiatry*, 14, 1208287. <https://doi.org/10.3389/fpsy.2023.1208287>
9. Martín-Fernández, J., Caballero-Estebarez, N., Félez, E., Pérez Del Rosario, P., Rodríguez Pulido, F., ... & Martín-Monzón, I. (2025). Introducing e-Motions: a novel intraoperative test for social cognition mapping. Triple validation in normative, schizophrenia, and autism spectrum disorder populations. *Neurosurgical Review*, 48(1), 112-124. <https://doi.org/10.1007/s00701-025-06661-x>

INVESTIGATION OF GUT MICROBIOTA COMPOSITION IN PATIENTS WITH IGA NEPHROPATHY AND ITS ASSOCIATION WITH PROTEINURIA LEVELS

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Abstract

Background: Immunoglobulin A nephropathy (IgAN) is the most common primary glomerulonephritis leading to renal failure worldwide [1]. In recent years, the gut-kidney axis and gut microbiota dysbiosis have been considered crucial links in the pathogenesis of this disease [3, 6]. However, the exact molecular mechanisms connecting specific intestinal bacteria and their metabolites to proteinuria—the primary marker of kidney damage—still require systematic elucidation [4, 5].

Objective: The objective of this study is to analyze the quantitative and qualitative composition of the gut microbiota in patients with IgA nephropathy and to evaluate the correlation between these compositional changes (dysbiosis) and proteinuria levels based on recent international empirical and clinical studies [1, 2, 5].

Methods: A systematic analysis was conducted on clinical and experimental data involving 166 IgAN patients and 102 healthy controls [1, 2, 4]. Microbial profiling was performed using 16S rRNA gene sequencing and shotgun metagenomic sequencing on the Illumina platform [1, 5, 7]. Proteinuria parameters were quantified via the urinary protein-to-creatinine ratio (uACR) and 24-hour urine protein levels [1, 2, 4]. Short-chain fatty acids (SCFAs) were assessed via GC/MS [2], while Gd-IgA1 and downstream inflammatory markers were quantified via ELISA and Western blot [5, 8].

Results: Patients with IgAN exhibited prominent gut dysbiosis [1, 4, 5]. Pathogenic genera, including *Escherichia-Shigella* and *Eggerthella lenta*, were significantly enriched and displayed a strong positive correlation with elevated uACR and severe 24-hour proteinuria (≥ 1 g/24 h) [1, 4, 5]. Conversely, beneficial taxa like *Bifidobacterium* spp. and *Blautia* spp. were drastically depleted and negatively correlated with urinary Gd-IgA1 levels [1, 5]. Fecal caproic acid levels were sharply reduced, showing a robust negative correlation with 24-hour urinary protein excretion ($r = -0.415$, $P = 0.025$) [2]. Metagenomic functional analysis revealed an overrepresentation of glycan-modifying bacterial enzymes (Flavonifractor plautii) involved in Gd-IgA1 synthesis [7]. In experimental models, fecal microbiota transplantation (FMT) from IgAN patients into pseudo-germ-free mice induced severe intestinal barrier dysfunction, activated the mucosal LPS/TLR4 inflammatory cascade, and triggered significant proteinuria [5, 8].

Conclusion: Gut microbiota dysbiosis is intrinsically linked to the severity of proteinuria in IgAN patients [1, 2, 4]. The overgrowth of pathogenic bacteria and the loss of protective SCFA-producing taxa drive the hyperproduction of nephrotoxic Gd-IgA1 via the LPS/TLR4 signaling pathway and bacterial glycan-modifying enzymes, causing filtration barrier breakdown [5, 7, 8]. Targeted restoration of the gut microbiome represents a highly promising therapeutic strategy to mitigate proteinuria and delay renal progression [5].

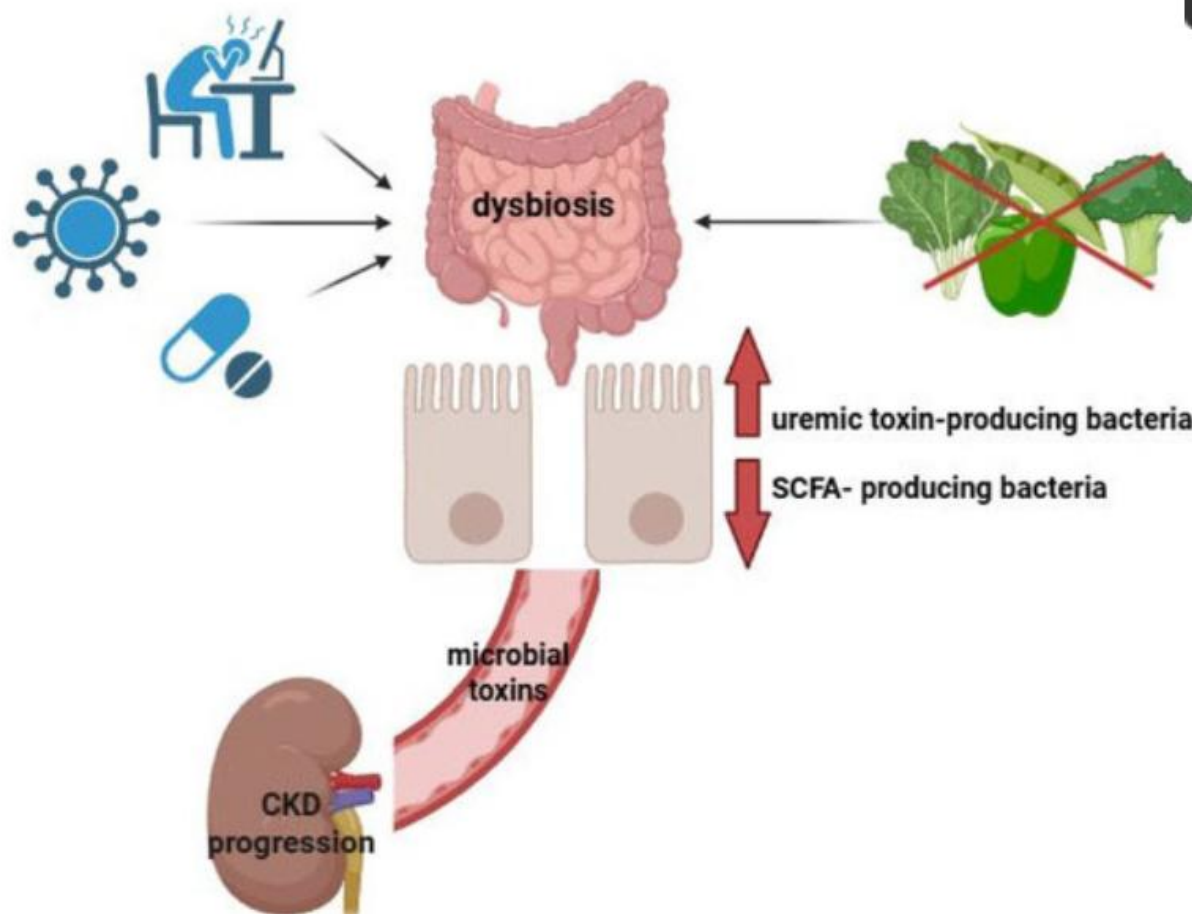
Keywords: IgA nephropathy, gut microbiota, proteinuria, dysbiosis, gut-kidney axis, Gd-IgA1, TLR4.

Introduction:

The pathophysiology of IgA nephropathy is primarily characterized by the deposition of galactose-deficient IgA1 (Gd-IgA1) molecules and the corresponding pathogenic immune complexes in the glomerular mesangial region [3, 5]. Recent scientific findings demonstrate that these nephrotoxic Gd-IgA1 molecules are initially produced on the mucosal surfaces of the gut rather than in the systemic circulation [3, 7].

Under physiological conditions, the gut microbiota regulates immune homeostasis [6]. However, disruption of the microflora (dysbiosis) leads to the proliferation of pathogenic bacteria and a reduction in protective metabolites [1, 2]. This process increases intestinal barrier permeability, facilitating the translocation of bacterial endotoxins (LPS) into the bloodstream and triggering inflammatory cascades that damage the kidneys [5, 8]. This impairment of the renal filtration barrier clinically manifests as the excretion of protein in the urine—proteinuria [1, 4]. Consequently, studying the composition of the gut microbiota and its relationship with proteinuria levels represents a critical scientific objective [2, 5].

Figure 1.



2. METHODS

This study comprehensively analyzed the methodologies of international clinical and experimental research investigating the relationship between IgA nephropathy and the gut microbiota:

1. *Clinical Cohort Selection:* The analyzed studies evaluated the clinical data of a total of 166 patients (including both untreated and treated IgAN patients) and 102 healthy controls (HC) [1, 2, 4]. Patients were matched for age, sex, and body mass index (BMI) [1, 5].

2. *Microbiome Analysis Methods:* Bacterial DNA was extracted from the fecal samples of the subjects, and the composition of the gut flora was determined by sequencing the V3-V4 regions of the 16S ribosomal RNA (rRNA) gene [1, 4]. To determine the comprehensive genomic profile and microbial enzymes, shotgun metagenomic sequencing was performed on the Illumina platform [5, 7]. Functional profiles were predicted using the MetaCyc and bioBakery 3 platforms [7].

3. *Biochemical and Immunological Assays:* The severity of proteinuria was assessed via the urinary protein-to-creatinine ratio (uACR) and 24-hour urine protein levels [1, 2, 4]. Fecal short-chain fatty acids (SCFAs) were measured using gas chromatography-mass spectrometry (GC/MS) [2]. Serum and urinary Gd-IgA1 levels, along with inflammatory markers (TLR4, LBP, sCD14, TNF- α), were analyzed using ELISA and Western blot assays [5, 8].

4. *Experimental Models:* To establish the direct impact of the gut microbiota, pseudo-germ-free mouse models were generated by depleting the endogenous flora with antibiotics, followed by fecal microbiota transplantation (FMT) from IgAN patients [5].

3. Results

The findings demonstrated that patients with IgA nephropathy exhibit profound gut dysbiosis compared to healthy individuals [1, 4, 5].

Table 1. Changes in Gut Microbiota and Their Association with Proteinuria Parameters in IgA Nephropathy

Bacteria/ Metabolite Name	Abundance Level in IgAN	Association with Urinary Protein (Proteinuria) and Renal Function	Data Source (References)
<i>Escherichia-Shigella</i>	Significantly Enriched	Positively correlated with uaCR levels elevated in severe 24-h proteinuria ($>1\text{g}/24\text{h}$); inversely correlated with eGFR	[1,4,5]
<i>Eggerthella lenta</i>	Enriched	Shows a direct positive correlation with the increase in urinary protein to-creatinine ratio (proteinuria severity)	[4,5]
<i>Ruminococcus bromii</i>	Enriched	Directly and positively correlated with the urinary protein to creatinine ratio	[4]
<i>Bifidobacterium spp.</i>	Significantly Depleted	Extremely low abundance in patients with severe proteinuria ($>1\text{g}/24\text{h}$); negatively correlated with urinary Gd-IgA1 levels;	[1,5]
<i>Blautia spp.</i>	Significantly Depleted	Decreased in patients with high urinary protein levels; shows an inverse correlation with urinary Gd-IgA1 levels	[1,5]
<i>Prevotella7</i>	Depleted	Negatively correlated with inflammatory markers (LBP, sCD14, TNF- α) and Gd-IgA1 levels.	[5]
Caproic acid	Reduced	Exhibits a strong negative correlation with elevated 24-hours urinary protein levels ($r=-0.415$, $P=0.025$)	[2]

Textual Description of Microbiota Composition and Proteinuria Correlation: According to clinical data, the genus *Escherichia-Shigella* shows a direct positive correlation with the urinary albumin-to-creatinine ratio (uACR) and manifest 24-hour proteinuria ($\geq 1\text{g}/24\text{h}$), while being associated with a decline in the estimated glomerular filtration rate (eGFR) [1, 4, 5]. *Eggerthella lenta* and *Ruminococcus bromii* were also found to display a direct positive correlation with the increase in the urinary protein-to-creatinine ratio (proteinuria grade) [4, 5]. Conversely, beneficial taxa such as *Bifidobacterium spp.* and *Blautia spp.* are present in minimal amounts in patients with high 24-hour protein excretion ($\geq 1\text{g}/24\text{h}$), and the depletion of these bacteria shows a strong inverse correlation (negative correlation) with elevated levels of urinary Gd-IgA1 (the aberrant protein) [1, 5]. Furthermore, the genus *Prevotella 7* was negatively correlated with systemic inflammatory markers (LBP, sCD14, TNF- α) [5] and Gd-IgA1 levels.

Alterations in Metabolites and Bacterial Enzymes:

Fecal levels of short-chain fatty acids (SCFAs) were sharply decreased in IgAN patients [2]. Notably, the reduction in caproic acid demonstrated a robust negative correlation with increased 24-hour urinary protein levels ($r = -0.415$, $P = 0.025$) [2]. Concurrently, metagenomic analysis confirmed an overrepresentation of glycan-modifying bacterial enzymes, specifically α -galactosidase and α -N-acetyl-galactosaminidase secreted by *Flavonifractor plautii*, which stimulate the generation of Gd-IgA1 [7].

Experimental Findings:

1. **Fecal Microbiota Transplantation (FMT):** Pseudo-germ-free mice colonized with the microbiota of IgAN patients exhibited increased intestinal barrier permeability, up-regulated inflammatory pathways in the gut, and developed severe renal injury (marked proteinuria) [5]. Conversely, FMT from healthy controls exerted a protective effect [5].

2. **Efficacy of Therapeutic Interventions:** Treatment with glutamine enteric-coated capsules (GEC) to restore gut barrier integrity and the administration of anti-TLR4 antibodies significantly reduced urinary protein excretion, serum creatinine, and blood urea nitrogen (BUN) in mice [5, 8].

4. Discussion

The empirical and metagenomic findings clarify a definitive molecular bridge between gut dysbiosis and the progression of proteinuria within the framework of the gut-kidney axis [3, 6]. The overgrowth of pathogenic bacteria such as *Escherichia-Shigella* and *Eggerthella lenta* disrupts the barrier function of the intestinal mucosa [4, 5]. This compromised barrier permits lipopolysaccharides (LPS), derived from the outer membrane of these bacteria, to translocate into the systemic circulation [5, 8]. Circulating LPS activates Toll-like receptor 4 (TLR4) on immune cells [5, 8]. This process stimulates mesenteric B cells and peripheral blood mononuclear cells (PBMCs), prompting the overproduction of nephrotoxic Gd-IgA1 molecules [5]. Additionally, glycan-modifying enzymes secreted by bacteria like *Flavonifractor plautii* cleave galactose sugars from normal IgA1 structures, accelerating Gd-IgA1 formation [7]. These immune complexes subsequently deposit in the renal glomerular mesangium, igniting an inflammatory cascade [3, 5]. As a consequence, the renal filtration barrier is damaged, allowing protein to leak into the urine and leading to clinically manifest proteinuria [1, 4]. Conversely, the depletion of beneficial SCFA metabolites,

such as caproic acid, signifies the loss of crucial factors that normally suppress these inflammatory processes [2].

5. Conclusion

Patients with IgA nephropathy present with distinct gut dysbiosis [1, 4]. The proliferation of pathogenic flora (*Escherichia-Shigella*, *Eggerthella lenta*) alongside the depletion of beneficial bacteria (*Bifidobacterium*, *Blautia*) and protective metabolites (SCFAs, caproic acid) directly correlates with the urinary protein-to-creatinine ratio and 24-hour proteinuria levels [1, 2, 4]. Gut dysbiosis drives the overproduction of Gd-IgA1 via the LPS/TLR4 signaling pathway and bacterial enzymes, ultimately causing renal filter disruption and the exacerbation of proteinuria [5, 7, 8]. Targeted restoration of the intestinal microenvironment represents a promising therapeutic avenue for reducing proteinuria levels [5].

Acknowledgements

I express my deepest gratitude to all investigators and academic colleagues whose clinical data and experimental findings made this study possible. I am also profoundly grateful to the PubMed database for providing the essential biomedical literature and open-access research resources that served as the core foundation for compiling and synthesizing the data on the gut-kidney axis in this article.

References

1. Hu X, Du J, Xie Y, Huang Q, Xiao Y, Chen J, Yan S, Gong Z, Ouyang S. Fecal microbiota characteristics of Chinese patients with primary IgA nephropathy: a cross-sectional study. *BMC Nephrol.* 2020;21(1):97. PMID: 32169051.
2. Chai L, Luo Q, Cai K, Wang K, Xu B. Reduced fecal short-chain fatty acids levels and the relationship with gut microbiota in IgA nephropathy. *BMC Nephrol.* 2021;22(1):209. PMID: 34082732.
3. Monteiro RC, Rafeh D, Gleeson PJ. Is There a Role for Gut Microbiome Dysbiosis in IgA Nephropathy? *Microorganisms.* 2022;10(4):683. PMID: 35456735.
4. Zhong Z, Tan J, Tan L, Tang Y, Qiu Z, Pei G, Qin W. Modifications of gut microbiota are associated with the severity of IgA nephropathy in the Chinese population. *Int Immunopharmacol.* 2020;89(Pt B):107085. PMID: 33068859.
5. Tang Y, Xiao Y, He H, Zhu Y, Sun W, Hu P, Xu X, Liu Z, Yan Z, Wei M. Aberrant Gut Microbiome Contributes to Barrier Dysfunction, Inflammation, and Local Immune Responses in IgA Nephropathy. *Kidney Blood Press Res.* 2023;48(1):150-161. PMID: 36878203.
6. Jin Y, Zhang SJ, Zhuang S, Li P, Miao H, Zhao YY. Microbiota-gut-kidney axis in health and renal disease. *Int J Biol Sci.* 2024;20(4):1250-1265. PMID: 41522358.
7. Liang X, Zhang S, Zhang D, Hu L, Zhang L, Peng Y, Xu Y, Hou H, Zou C, Liu X, Chen Y, Lu F. Meta-genomics-based systematic analysis reveals that gut microbiota Gd-IgA1-associated enzymes may play a key role in IgA nephropathy. *Front Mol Biosci.* 2022;9:970723. PMID: 36090029.
8. He H, Shen M, Tang Y, Sun W, Xu X. LPS/TLR4 Pathway Regulates IgA1 Secretion to Induce IgA Nephropathy. *Alternative Therapies in Health & Medicine.* 2023. PMID: 37820669.

DYNAMICS OF IMMUNOLOGICAL PARAMETERS AND MICROBIOTA COMPOSITION IN ORAL FLUID AND BLOOD IN CHILDREN AND ADOLESCENTS WITH CHRONIC FORMS OF GINGIVITIS

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Relevance. It is known that the main factors in the pathogenesis of periodontal diseases (PD) are infection and poor oral hygiene (OH). The hygienic status of the oral cavity (OC) in children and adolescents remains low, and therefore the inflammatory process that develops in periodontal tissue (PT) under the influence of microbial aggression requires targeted correction [2], since chronic gingivitis (CG) is accompanied by impaired blood microcirculation in the gingival blood vessels [1]. Immune and hormonal shifts play a significant role in the pathogenesis of CG. Adolescent gingivitis is caused by the acquisition of pathogenic properties by resident microflora as a result of reduced local immunity [3,4].

Aim of the study. To determine the microbiological and immunological (Ig) parameters characteristic of chronic inflammatory gingivitis (CIG) among children and adolescents in order to optimize the diagnosis and treatment of these pathological processes.

Material and methods. A total of 425 children and adolescents were selected, including 195 (45.9%) with chronic catarrhal gingivitis, CCG (group 1), 165 (38.9%) with chronic hypertrophic gingivitis, CHG (group 2), and 65 (15.3%) practically healthy subjects (control group, CG) with respect to periodontal tissue; they were also divided into age groups and by sex.

A survey, objective examination of the oral cavity, and generally accepted clinical-laboratory and dental examination methods were performed. The Mancini radial immunodiffusion method was also used to determine changes in blood Ig levels, along with culture testing to assess the microbiota (MO) status of oral fluid (OF) and gingival sulcus (GS) contents. The study was conducted at the bacteriological laboratory of the Department of Microbiology, CDPQMW, Ministry of Health of the Republic of Uzbekistan. Microorganisms were isolated from their natural habitat — oral fluid and gingival sulcus contents — by inoculating the test materials onto artificial nutrient media using the culture method. The results obtained were processed using generally accepted statistical methods: the initial quantitative parameters were tabulated in MS Excel version 7.0 and analyzed using the "Descriptive Statistics" module of the STATISTICA 6.1 applied statistical software package under Windows.

Results and discussion. It was established that the main complaint of group 1 patients was gum bleeding, present in 63.6%, with bleeding occurring during tooth brushing in 6.1% of children; dental calculus (DC) was found in 23.03% of patients. In children and adolescents of group 2, inflammatory processes in the gums were noted in 67.9%, 80.1% of patients complained of pain and bleeding of the gums during tooth brushing, and dental calculus was found in 35.4% of patients.

Analysis of serum IgA, IgG, and IgM levels in groups 1 and 2 showed that patients with inflammation (Infl.) had deviations from the CG, with elevated Ig levels in the blood plasma. The highest Ig levels were observed in group 1. In the control group, these parameters were almost unchanged from generally accepted norms.

Examination of oral fluid and gingival sulcus contents revealed that in oral fluid, β -hemolytic streptococci, *Neisseria*, and *Candida albicans* fungi were most frequently found — in up to 31% of cases in group 1 and up to 24% in group 2. Compared with the control group, colonies of β -hemolytic streptococcus were found more often and in greater quantity in gingival sulcus contents — 3 times more in group 1 patients and 2.5 times more in group 2 patients; *Neisseria* in oral fluid was 2.5 times higher in group 1 and 1.9 times higher in group 2; and *Candida albicans* was 1.8 and 1.4 times higher, respectively.

References

1. Krechina E.K. Proceedings of the Second All-Russian Symposium "Application of Laser Doppler Flowmetry in Medical Practice." Moscow, 1998. pp. 54–56.

2. Kuzmina E.M., Prostakova T.B., Kondratov A.I. *New in Dentistry*. 1994. No. 2. pp. 23–25, 14, 23.
3. Loktionov A.L., Konoplya A.I., Lunev M.A., Karaulov A.V. Immune and oxidant disorders in the pathogenesis of inflammatory periodontal diseases. *Immunology*. 2015, 36(5), 319–328.
4. Nurmatova N.T., Gafforov S.A., Zhambylov R.S., Sobirov A.A., Yakubova F.X., Radjabov N.M., Ibragimov F.N. Clinical-functional and immune-microbiological features of the oral cavity in children and adolescents with chronic forms of gingivitis. *Edelweiss Applied Science and Technology*. ISSN: 2576-8484. Vol. 9, No. 7, 3371–3382, 2025.

THE ROLE OF GLUTEN IN THE PATHOGENESIS AND MANAGEMENT OF AUTOIMMUNE THYROID DISEASES: A SYSTEMATIC REVIEW

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Abstract

Background: In recent years, scientific interest has significantly increased regarding the association between gluten consumption and the development of autoimmune thyroid diseases (AITDs). Gluten is hypothesized to exacerbate thyroid autoimmunity through mechanisms such as dysbiosis, increased intestinal permeability, and molecular mimicry.

Objective: The objective of this study is to comprehensively evaluate and synthesize the global scientific evidence regarding the effects of a gluten-free diet (GFD) on the immune profiles, antibody titers, and thyroid function of patients diagnosed with Hashimoto's thyroiditis (HT) and celiac disease (CD).

Methods: A systematic review of recent international meta-analyses, clinical trials, and observational studies was conducted using comprehensive electronic databases (PubMed, Scopus, Google Scholar, Embase, Web of Science, Medline, and Cochrane). Studies evaluating changes in thyroid hormones (TSH, FT4) and autoantibodies (TPOAb, TgAb) under dietary modifications were analyzed.

Results: The results indicate that adherence to a GFD significantly reduces antibody levels (TPOAb, TgAb) and improves thyroid hormone profiles (TSH, FT4), particularly in the pediatric subgroup of celiac patients ($OR = 1.61$, 95% CI $1.06-2.43$, $P = 0.02$) and in drug-naïve women with latent gluten sensitivity. Furthermore, at the epigenetic level, eliminating gluten and casein was shown to restore the activity of regulatory T cells by reducing the methylation levels of the *foxp3* gene ($p < 0.0001$).

Conclusion: The clinical management of AITDs can be optimized through personalized nutritional strategies, such as gluten or casein elimination, alongside the targeted correction of essential micronutrient deficiencies (selenium, iodine, vitamin D).

Keywords: Hashimoto's thyroiditis, gluten-free diet, celiac disease, molecular mimicry, *foxp3* gene, antibodies.

Introduction:

Autoimmune thyroid diseases (AITDs), most notably Hashimoto's thyroiditis (HT), are among the most prevalent chronic inflammatory pathologies characterized by the progressive destruction of thyroid tissue. The pathogenesis of HT involves complex interactions between genetic predisposition and environmental triggers. Over the past decades, the rising incidence of gluten-related disorders (GRDs) and celiac disease (CD) has prompted extensive research into the extraintestinal autoimmune manifestations triggered by gluten proteins.

The pathological impact of gluten on the thyroid gland is driven by several key mechanisms. These include the disruption of the gut microbiota (dysbiosis), the compromise of the intestinal barrier leading to increased permeability ("leaky gut" syndrome), and cross-reactivity (molecular mimicry) arising from the structural homology between gliadin proteins and thyroid antigens. In routine clinical practice, management typically focuses exclusively on hormonal substitution therapy (levothyroxine), while the supportive role of dietary intervention is frequently overlooked. Therefore, systematizing the scientific evidence regarding the effects of a gluten-free diet (GFD) on thyroid autoimmunity is highly relevant to optimizing clinical outcomes.

Figure 1.

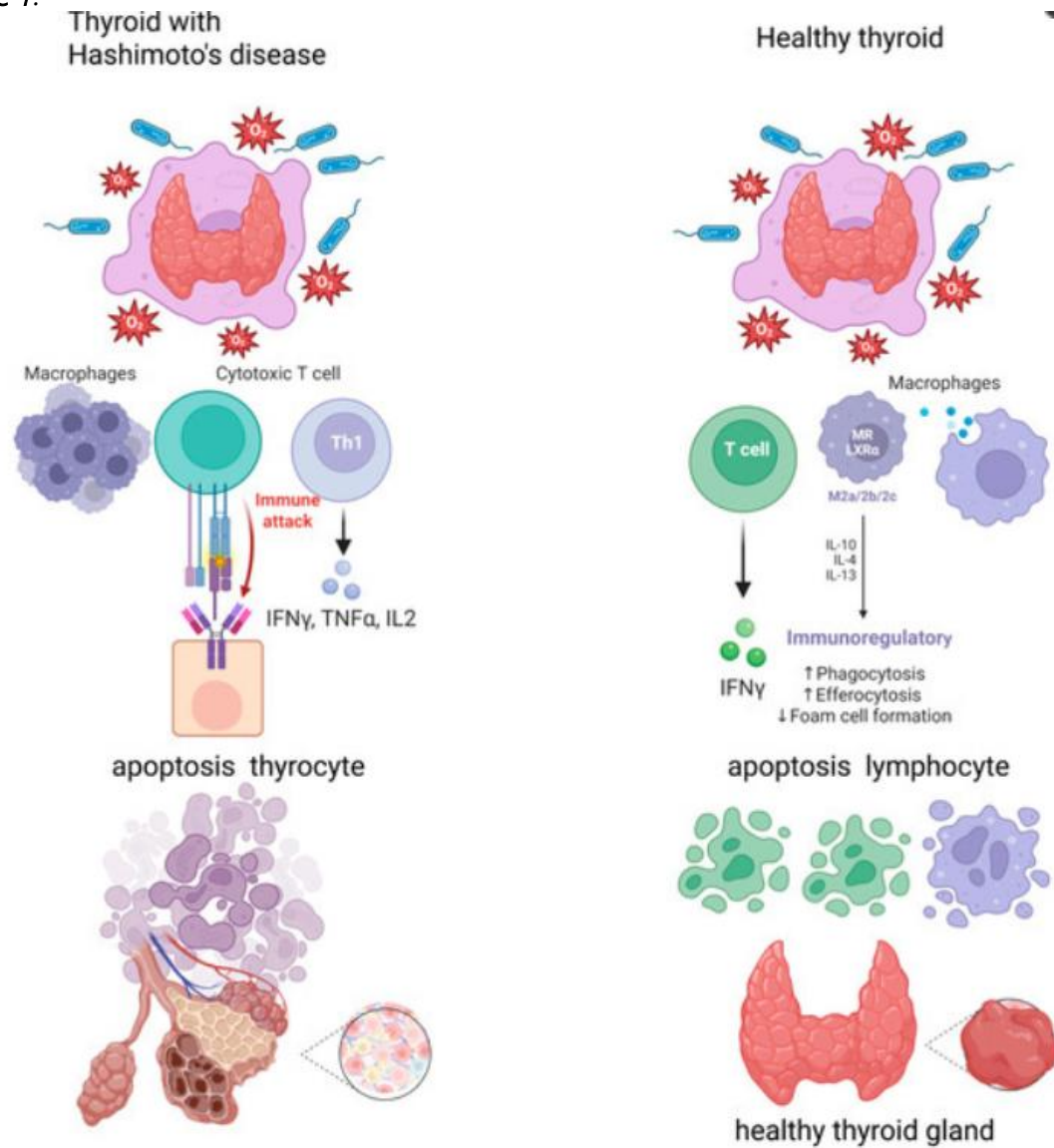
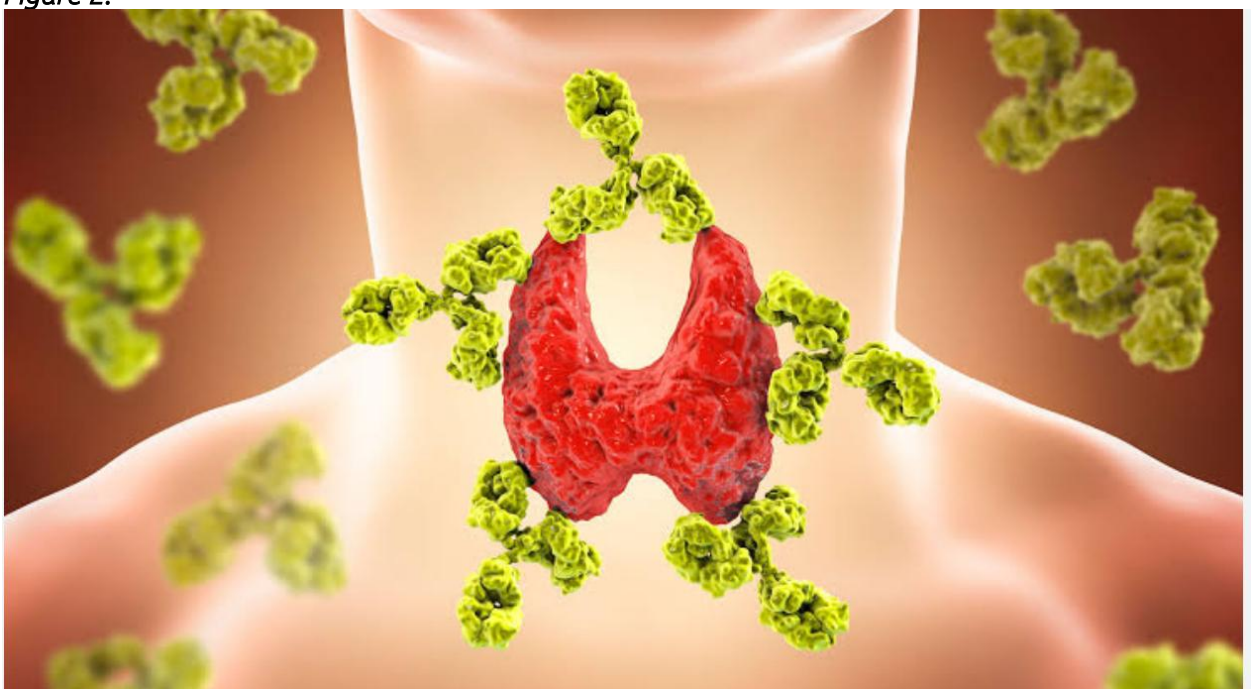


Figure 2.



2. METHODS

A systematic and narrative literature review was conducted using comprehensive electronic databases, including PubMed, Scopus, Google Scholar, Embase, Web of Science, Medline, and Cochrane. Search strategies utilized MeSH terms and keywords such as "Gluten", "Autoimmune thyroid disease", "Hashimoto's thyroiditis", and "Gluten-free diet".

The inclusion criteria focused on clinical trials, pilot studies, and observational meta-analyses that evaluated changes in thyroid hormones (TSH, FT4, FT3) and autoantibodies (TPOAb, TgAb) in HT patients with or without confirmed celiac disease. Additionally, recent laboratory experiments examining the impact of dietary patterns on DNA-level epigenetic modifications and regulatory T (Treg) cells (CD4⁺ foxp3⁺) were incorporated into the analysis.

3. Results

The analyzed meta-analyses and observational data revealed that the clinical efficacy of gluten deprivation varies significantly depending on patient sub-populations.

3.1. Age-Dependent Effects in Patients with Celiac Disease

A large-scale meta-analysis incorporating 10 observational studies with a total of 6,423 subjects evaluated the overall association between a GFD and thyroid autoimmunity. While no statistically significant difference in thyroid autoimmunity was observed in the overall adult CD population adhering to a GFD, a distinct positive association was found within the pediatric subgroup. Children with early-onset CD and more pronounced autoimmunity exhibited a significantly higher correlation between dietary compliance and improved thyroid antibody outcomes (OR = 1.61, 95% CI 1.06–2.43, $P = 0.02$).

3.2. Hormonal Dynamics in Patients Without Symptoms or Histology of Celiac Disease

In HT patients displaying no clinical symptoms or histological indicators of celiac disease, a 6-month adherence to a GFD resulted in a favorable downward trend in autoantibodies. The meta-analysis indicated an effect size (ES) of -0.39 ($p = 0.06$) for TgAb and -0.40 ($p = 0.07$) for TPOAb. More importantly, substantial improvements were documented in thyroid function: serum TSH levels significantly decreased (ES: -0.35, $p = 0.02$), while free thyroxine (FT4) levels showed a statistically significant increase (ES: +0.35%, $p = 0.02$).

3.3. Clinical Efficacy in Drug-Naïve Women

A clinical pilot study evaluated drug-naïve women diagnosed with HT who presented with incidentally positive anti-tissue transglutaminase antibodies. Following 6 months of a strict GFD, these patients demonstrated a significant reduction in serum TPOAb and TgAb titers. Additionally, slight increases were observed in serum 25-hydroxyvitamin D levels and the calculated SPINA-GT index (reflecting the thyroid's functional secretory capacity). Conversely, the control group maintaining a regular diet showed no significant variations in these parameters.

3.4. Epigenetic Mechanisms and FoxP3 Gene Regulation

Advanced methylation and epigenetic analyses investigated the structural changes in the foxp3 transcription factor—a critical regulator of anti-inflammatory regulatory T (Treg) cells. HT patients who adhered strictly to a diet excluding both gluten and casein (milk protein) exhibited a remarkable reduction in the methylation levels of the foxp3 gene ($p < 0.0001$). This epigenetic shift indicates enhanced gene expression, which helps suppress autoimmune-driven pro-inflammatory responses by supporting proper Treg cell differentiation.

The detailed characteristics of the primary scientific works analyzed in this review and their major outcomes are systematically compiled in Table 1.

Table 1.

Characteristics and outcomes of studies assessing the effects of a gluten-free diet (GFD) on thyroid autoimmunity and function.

Authors & Year	Study Type & Sample Size	Dietary Intervention & Duration	Key Laboratory Results & Parameters	Main Scientific Conclusion & Citation
Kimia Sadat Esfahani(2024)	Narrative literature review	Gluten-free diet(GFD)	Analysis of dysbiosis,leaky gut and cross-reactivity mechanisms	Gluten contributes to the progression of AITDs via the gut-thyroid axis
Yan Liu al(2024)	Meta-analysis of 10 observational studies (n=6423)	Gluten-free diet(GFD)	Children subgroup:OR=1,61 95% CI 1,06-2,43 P=0,03.No significant difference in the total adult CD population.	CFD shows pronounced protective benefits in early-onset celiac patients with higher baseline autoimmunity
Tommaso Pitticchio et al(2023)	Meta-analysis of 4 studies (n=87, non-celiac HT patients)	Gluten-free diet(GFD) average duration of 6 month	Significant reduction in TSH(p=0,02) and increase in FT4 (p=0,02) Downward trend for TgAb(p=0,06) and TPOAb(p=0,07)	Gluten deprivation positively influences thyroid function and inflammation even in the absence of celiac disease
Robert Krysiak et al.	Clinical pilot study (n=34, drug-naive women)	Strict GFD vs. regular diet for 6 months	Marked decrease in TPOAb and TgAb titers; mild increases in 25-hydroxyvitamin D and the Spina-GT index	A GFD brings clear clinical benefits to HT-diagnosed women with latent gluten sensitivity markers.
Elifeat al.(2024)	Epigenetic and methylation analysis	Casein-free and gluten-free diet(CFCFD)	Highly significant reduction in the methylation levels of the foxp3 gene (p<0,0001)	Nutritional intervention modulates autoimmunity at the DNA level by enhancing foxp3 gene expression and Treg cell development

4. Discussion

As compiled in Table 1, these findings highlight the fundamental role of the gut-thyroid axis in managing autoimmune disorders. The ingestion of gluten in sensitive individuals disrupts intestinal tight junctions, allowing undigested dietary peptides into systemic circulation ("leaky gut"). Due to structural similarities between gliadin and thyroid proteins, the resulting immune response inadvertently targets thyroid tissues through molecular mimicry.

The epigenetic data provides a breakthrough perspective, demonstrating that dietary interventions can go beyond mechanically reducing antibody exposure; they can actively regulate gene expression at the DNA level. Additionally, evidence suggests that combining a GFD with casein restriction, alongside careful monitoring of iodine balance, selenium, and vitamin D deficiencies, significantly multiplies the therapeutic efficacy in HT management.

However, the current body of clinical evidence remains insufficient to empirically mandate a strict GFD for all HT patients who lack celiac disease or distinct gluten-related conditions. Dietary strategies must be personalized, taking into account the patient's age, baseline autoantibody activity, and specific metabolic or clinical responses.

5. Conclusion

Dietary management, specifically the strict elimination of gluten and casein, serves as an effective complementary strategy to attenuate the autoimmune cascade, lower autoantibody titers (TPOAb, TgAb), and optimize thyroid hormone profiles (TSH, FT4) in responsive Hashimoto's thyroiditis patients. Future large-scale, randomized clinical trials are warranted to further clarify the long-term systemic impact of the gut-thyroid axis intervention.

Acknowledgements

I express my sincere gratitude to the authors of the primary studies and meta-analyses indexed in PubMed, whose valuable scientific data and research findings laid the foundation for this systematic review. Their significant contributions to the field of celiac disease and thyroid autoimmunity made the comprehensive analysis in this paper possible.

References

1. Esfahani, K. S., Asri, N., Ghehsareh, M. M., Rezaei-Tavirani, M., Jahani-Sherafat, S., & Rostami-Nejad, M. (2024). The Role of Gluten in the Development of Autoimmune Thyroid Diseases: A Narrative Review. *Iranian Journal of Endocrinology and Metabolism*. PMID: 40065831.

2. Liu, Y., Yao, N., Wang, Y., Dong, Y., Wang, L., Wang, F., Wu, Z., Wang, S., & Li, B. (2024). *The association of gluten-free diet with thyroid autoimmunity in patients with celiac disease: a meta-analysis.* *Food & Function.* PMID: 38205645.
3. Aslan, E. S., Meral, G., Aydin, E., Caglayan, S., Altundag, A., Demirkol, S., Gormus, G., Solak, M., & Ayaz, F. (2024). *The Effect of a Casein and Gluten-Free Diet on the Epigenetic Characteristics of FoxP3 in Patients With Hashimoto's Thyroiditis.* *Cureus.* PMID: 38952602.
4. Piticchio, T., Frasca, F., Malandrino, P., Trimboli, P., Carrubba, N., Tumminia, A., Vinciguerra, N., & Frittitta, L. (2023). *Effect of gluten-free diet on autoimmune thyroiditis progression in patients with no symptoms or histology of celiac disease: a meta-analysis.* *Frontiers in Endocrinology.* PMID: 37554764.
5. Lontiris, M. I., & Mazokopakis, E. E. (2017). *A concise review of Hashimoto thyroiditis (HT) and the importance of iodine, selenium, vitamin D and gluten on the autoimmunity and dietary management of HT patients. Points that need more investigation.* *Hellenic Journal of Nuclear Medicine.* PMID: 28315909.
6. Krysiak, R., Szkróbka, W., & Okopień, B. (2019). *The Effect of Gluten-Free Diet on Thyroid Autoimmunity in Drug-Naïve Women with Hashimoto's Thyroiditis: A Pilot Study.* *Experimental and Clinical Endocrinology & Diabetes.* PMID: 30060266.

TAKOTSUBO CARDIOMYOPATHY ("BROKEN HEART SYNDROME"): NEUROCARDIAC MECHANISMS OF PSYCHOEMOTIONAL STRESS-INDUCED MYOCARDIAL DYSFUNCTION

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Abstract

Relevance: Standing at the intersection of psychosomatics and modern cardiomyopathy, Takotsubo syndrome (TTS) has increasingly drawn the attention of the scientific community due to its significant pathological burden. Initially considered a benign condition, this syndrome is challenging to distinguish from acute coronary syndrome (ACS) and carries a substantial risk of morbidity and mortality. Therefore, investigating the neurocardiac mechanisms through which severe psychoemotional stress temporarily damages the myocardium via the brain-heart axis is highly relevant in contemporary cardiology.

Objective: The objective of this scientific review is to systematically analyze the neurocardiac mechanisms in the pathogenesis of Takotsubo syndrome using international PubMed data, evaluate the cardiotoxic effects of catecholamines, characterize the clinical differences between negative ("broken heart") and positive ("happy heart") triggers, and delineate modern diagnostic and therapeutic strategies.

Methods: A comprehensive systematic review of international, peer-reviewed scientific papers and case reports indexed in the PubMed database was performed using specific keywords such as "Takotsubo cardiomyopathy," "brain-heart axis," and "happy heart syndrome."

Results and Conclusion: The literature demonstrates that a sudden surge of stress hormones (catecholamines) targets β -adrenergic receptors primarily located at the cardiac apex, causing transient left ventricular contractile dysfunction. Given the clinical importance of the pathology, its "positive" and "negative" variants were classified, and current management protocols were systematically organized into reference tables.

Keywords: Takotsubo cardiomyopathy, broken heart syndrome, happy heart syndrome, brain-heart axis, catecholamines, limbic system.

Introduction:

One of the most enigmatic phenomena in psychosomatic cardiology is Takotsubo syndrome, also widely known as "broken heart syndrome," "stress-induced cardiomyopathy," or "transient left ventricular apical ballooning syndrome.". This pathology was first described in Japan in the early 1990s. The name of the syndrome originates from the unique morphological distortion of the left ventricle (LV) during systole, where the apex balloon-like dilates while the neck remains narrow, mimicking the shape of a "takotsubo"—a traditional Japanese clay pot with a round bottom and narrow neck used for trapping octopuses.

For a long time, this syndrome was regarded as a clinically benign and spontaneously reversible mild disorder. However, recent studies have demonstrated that this pathology is far from benign, carrying substantial morbidity and mortality rates comparable to those of acute coronary syndrome (ACS). Takotsubo syndrome accounts for approximately 2–3% of all suspected acute coronary syndromes and exhibits a strong predilection for postmenopausal, older women.

The defining hallmark of this syndrome is that its onset is typically precipitated by a sudden, severe psychoemotional or physical stressor. It is now medically proven that the heart can undergo this profound dysfunction not only from severe grief or bereavement ("broken heart") but also following unexpected, overwhelmingly positive life events ("happy heart syndrome"). Consequently, exploring the pathophysiological mechanisms through which emotions are transmitted from the brain to the heart remains a critical scientific endeavor.

Figure 1.

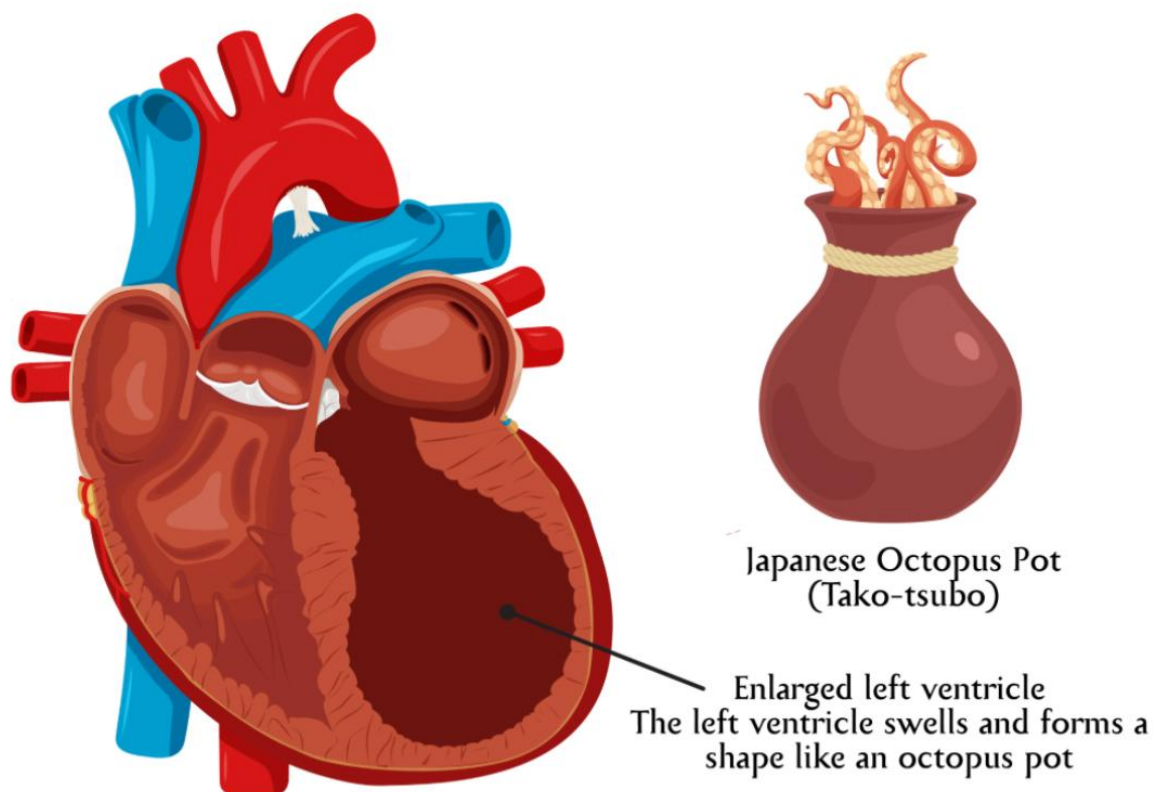
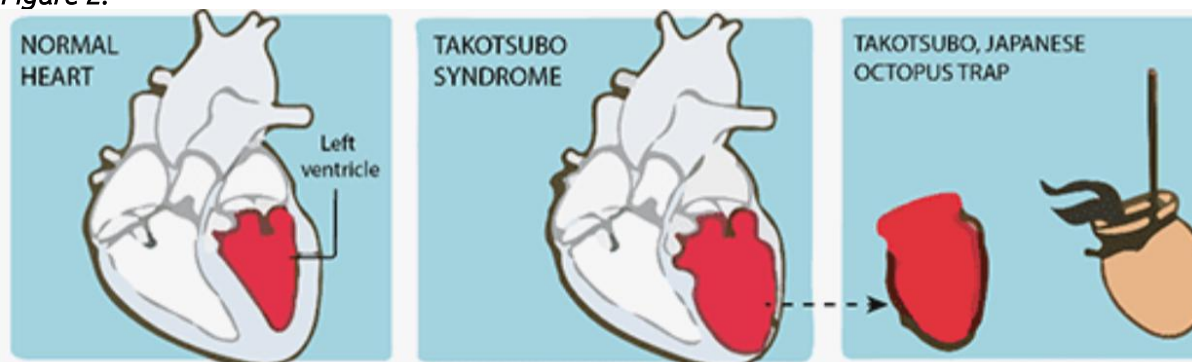


Figure 2.



2. METHODS

This study performed a rigorous scientific review of recent systematic reviews, meta-analyses, and clinical case reports available in the international PubMed/MEDLINE database.

The search strategy employed standard Boolean operators and specific keywords, including: "Takotsubo cardiomyopathy", "broken heart syndrome", "happy heart syndrome", "catecholamine-induced cardiotoxicity", and "brain-heart axis". Only peer-reviewed articles from high-impact journals detailing the etiology, pathophysiology, diagnostic criteria, and clinical outcomes of Takotsubo syndrome were selected for final analysis.

3. Results

The review of scientific literature confirms that the clinical presentation of Takotsubo syndrome closely mimics that of an acute myocardial infarction. Patients most frequently present with acute chest pain (tightness), dyspnea, and pulmonary edema, which can more rarely progress to cardiogenic shock. Electrocardiogram (ECG) changes typically demonstrate ST-segment elevation or T-wave inversion. However, emergent coronary angiography characteristically rules out acute coronary obstruction, mechanical blockage, or ruptured atherosclerotic plaques.

Based on the analyzed data, a comparative analysis was established between the two primary emotional variants of Takotsubo syndrome ("Broken Heart" vs. "Happy Heart") and is outlined in Table 1.

Table 1.

Clinical Profiles of TTS Based on Emotional Triggers

<i>Clinical Characteristics</i>	<i>Broken Heart Syndrome</i>	<i>Happy Heart Syndrome</i>
<i>Primary Trigger</i>	<i>Severe grief, loss of a loved one, panic/anxiety, domestic violence, financial crises</i>	<i>Unexpected grand joy, birthday parties, weddings, winning a lottery, major sports victories</i>
<i>Patient population</i>	<i>Predominantly postmenopausal women (>90%)</i>	<i>Postmenopausal women, though the proportion of male patients is higher compared to broken heart</i>
<i>Cardiac Injury Zone</i>	<i>Primarily apical (classic apical ballooning of the left ventricle)</i>	<i>More frequently mid-ventricular or basal wall abnormalities</i>
<i>Pathophysiology</i>	<i>Sudden surge of catecholamines and sympathetic nervous system hyperactivation</i>	<i>Sudden surge of catecholamines and sympathetic nervous system hyperactivation</i>
<i>Prognosis & Recovery</i>	<i>Full recovery in ~95% of cases after surviving the acute phase</i>	<i>Full recovery in ~95% of cases within a few weeks</i>

Furthermore, modern neuroimaging studies indicate that TTS development involves not only the cardiovascular system but also structural and functional alterations within the central nervous system, particularly the emotional processing hubs of the limbic system.

4. DISCUSSION

Although the exact pathophysiological mechanisms underlying Takotsubo syndrome remain partially elusive, the leading contemporary hypothesis centers on the disruption of the brain-heart axis and catecholamine-induced cardiotoxicity.

During severe psychoemotional stress (whether negative or positive), cognitive and emotional centers in the brain—specifically the amygdala and the limbic system—trigger an exaggerated activation of the sympathetic nervous system. This results in a massive, abrupt release of adrenaline and noradrenaline into the bloodstream, termed a "catecholamine surge."

The density of β -adrenergic receptors within the myocardium is not uniform; the concentration of β -receptors is significantly higher at the cardiac apex (tip) compared to its base. Toxic concentrations of circulating catecholamines overstimulate these apical receptors, precipitating microvascular dysfunction and myocardial stunning. Consequently, while the basal segments of the heart remain hypercontractile, the apex fails to contract and balloon-dilates, generating the characteristic "takotsubo" morphology.

Currently, evidence-based management data for Takotsubo syndrome derived from randomized controlled trials (RCTs) remain limited. Treatment is largely supportive and symptomatic, prioritizing the stabilization of left ventricular function during the acute phase (Table 2).

Table 2.

Therapeutic Management Framework for Takotsubo Syndrome

<i>Medication Class</i>	<i>Mechanism of Action and Therapeutic Goal</i>
<i>ACE Inhibitors/ARBs</i>	<i>Used if left ventricular ejection fraction drops below 40% to improve long-term function and reduce the risk of recurrence</i>
<i>Beta-blockers (e.g., Carvedilol)</i>	<i>Utilized to blunt excessive sympathetic drive and safeguard the myocardium against catecholamine toxicity</i>
<i>Anxiolytics/Sedatives</i>	<i>Administered to modulate the psychosomatic axis by suppressing acute psychological stress and anxiety</i>

The most encouraging clinical attribute of this syndrome is its transient nature. Once patients are stabilized through acute complications (such as arrhythmias or cardiogenic shock), approximately 95% of individuals achieve a complete spontaneous reversal of myocardial dysfunction and full cardiovascular recovery within 3 to 4 weeks.

5. CONCLUSIONS

Takotsubo cardiomyopathy serves as a profound clinical manifestation of the direct nexus linking the human mind (psychis) to physical health (cardiology). Extreme grief and unexpected joy act as equivalent neurocardiac stressors capable of inducing localized myocardial stunning via catecholamine hyperactivation. Because TTS is clinically indistinguishable from acute myocardial infarction, emergency coronary angiography remains the gold standard to rule out obstructive coronary artery disease. Future interdisciplinary research between cardiology and neuropsychiatry is essential to establish standardized, evidence-based management and preventive protocols.

ACKNOWLEDGMENTS

The author expresses sincere gratitude to the international scientific community and authors whose foundational research and clinical case reports made this review possible: Brenton Boyd and Tia Solh; Diane Nykamp and John Titak; Gurpreet Singh Chahal and co-researchers; Jayant Ravindran and David Brieger; Hilman Amin and colleagues; Álvaro Aparisi and Aitor Uribarri; Mitchell Elkind; and Joseph

Adu-Amankwaah for his pivotal work clarifying the "happy heart" phenomenon. Their dedication continues to advance the landscape of psychosomatic cardiovascular medicine.

References

1. Boyd B, Solh T. Takotsubo cardiomyopathy: Review of broken heart syndrome. *JAA*. 2020;33(2):35-39. PMID: 32039951.
2. Nykamp D, Titak JA. Takotsubo cardiomyopathy, or broken-heart syndrome. *Ann Pharmacother*. 2010;44(2):390-393. PMID: 20124462.
3. Chahal GS, Polena S, Fard BS, et al. Takotsubo cardiomyopathy: case report and review of the literature. *J Med Case Reports*. 2009;3:7451. PMID: 19544675.
4. Ravindran J, Brieger D. Clinical perspectives: Takotsubo cardiomyopathy. *Intern Med J*. 2024;54(9). PMID: 39248550.
5. Amin HZ, Amin LZ, Pradipta A. Takotsubo Cardiomyopathy: A Brief Review. *J Med Life*. 2020;13(1):3-7. PMID: 32341693.
6. Aparisi Á, Uribarri A. Takotsubo syndrome. *Med Clin (Barc)*. 2020;155(2):77-82. PMID: 32654831.
7. Elkind MSV. Takotsubo Cardiomyopathy: At the Nexus of the Heart, Brain, and Mind. *JACC Heart Fail*. 2023;11(3):318-320. PMID: 36881390.
8. Adu-Amankwaah J. "Happy Heart" Versus "Broken Heart" Syndrome: The 2 Faces of Takotsubo Syndrome: Similarities and Differences. *JACC Heart Fail*. 2022;10(7):511-513. PMID: 35772856.
9. Omerovic E, Redfors B. Takotsubo syndrome: pathophysiological insights and innovations in patient care. *Nat Rev Cardiol*. 2025;22(5). DOI: 10.1038/s41569-025-01211-5. PMID: 41039160.

EFFICACY AND SAFETY PROFILE OF BIOLOGICAL THERAPY IN THE MANAGEMENT OF CHRONIC RHINOSINUSITIS WITH NASAL POLYPS: A COMPREHENSIVE REVIEW BASED ON INTERNATIONAL PHASE 3 CLINICAL TRIALS

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Abstract

Background: Chronic rhinosinusitis with nasal polyps (CRSwNP) is a severe inflammatory disease of the sinonasal mucosa that significantly degrades patient quality of life. The underlying pathophysiology is primarily driven by type 2 helper T-cell (Th2) mediated inflammation. Conventional therapeutic options, such as intranasal or systemic glucocorticosteroids and repeated endoscopic sinus surgeries, often yield temporary relief and carry substantial risks of recurrence and long-term toxicity.

Objective: This study aims to systematically evaluate and synthesize the clinical efficacy, biomolecular mechanisms, and long-term safety profiles of modern monoclonal antibodies (biologics) targeted against type 2 pathways, utilizing data from recent global phase 3 clinical trials.

Methods: A comprehensive, compilative analysis of high-evidence clinical data was executed using the PubMed, Medline, and Cochrane databases. The scope included landmark phase 3 trials such as WAYPOINT, SYNAPSE, ANCHOR-1, ANCHOR-2, and multicenter biomarker evaluations of dupilumab. Key end-points evaluated were changes in the endoscopic Nasal Polyp Score (NPS), the Visual Analogue Scale (VAS) for nasal obstruction, systemic corticosteroid rescue reliance, and the statistical reduction in the necessity for surgical intervention.

Results: Tezepelumab effectively reduced the absolute need for nasal surgery from 22.1% (placebo) to 0.5% at week 52 ($P < 0.001$). Mepolizumab demonstrated robust efficacy in highly refractory cohorts, improving the VAS nasal obstruction score by a mean of -3.14 points. At the molecular level, dupilumab induced sustained suppression of type 2 inflammatory indicators, yielding a median decrease in serum TARC by up to -88.6%, plasma eotaxin-3 by -51.5%, and total serum IgE by -76.7%. Ultra-long-acting depemokimab demonstrated stable clinical improvement with a twice-yearly dosing interval, while the novel agent stapokibart was established as a viable alternative following its recent regulatory approvals.

Conclusion: Biologics offer a highly potent, targeted therapeutic paradigm for severe, recalcitrant CRSwNP. While they successfully minimize disease burden and surgical necessity, unique clinical phenomena such as transient, treatment-induced hypereosinophilia require vigilant, algorithm-driven management rather than premature treatment cessation.

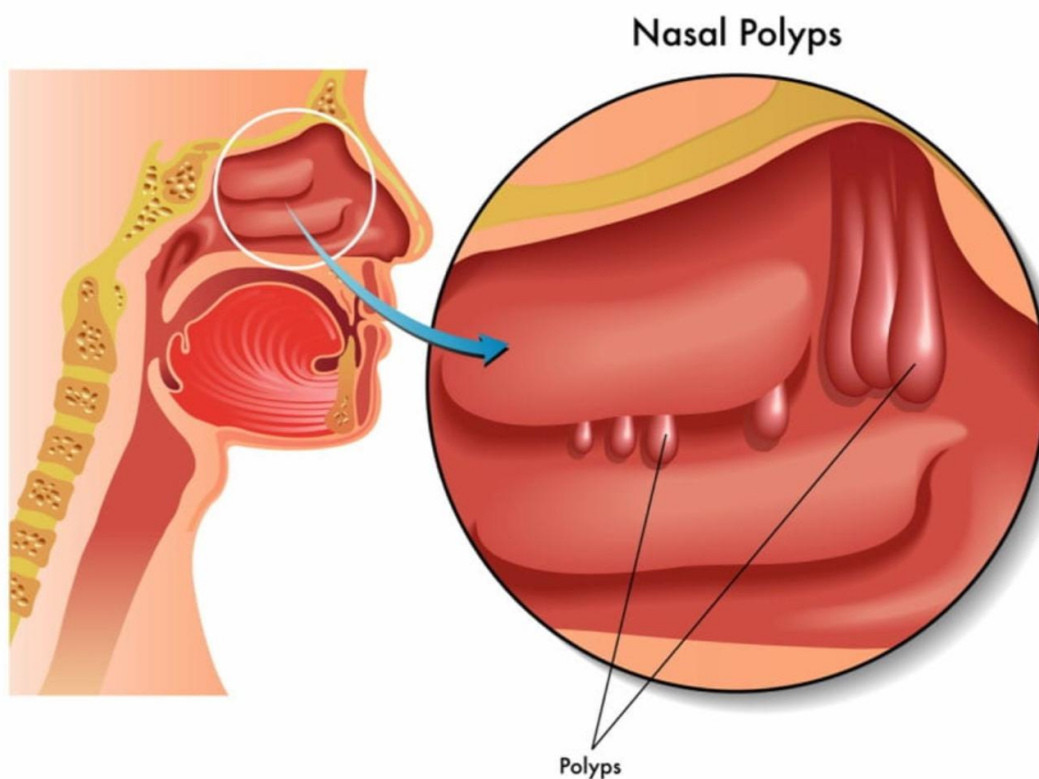
Keywords: chronic rhinosinusitis, nasal polyps, monoclonal antibodies, biological therapy, type 2 inflammation

Introduction:

Chronic rhinosinusitis with nasal polyps (CRSwNP) represents a highly challenging clinical phenotype of chronic upper airway inflammation, affecting approximately 2% to 4% of the global population. The disease is characterized by persistent nasal congestion, rhinorrhea, facial pain, and a progressive loss of olfaction. For decades, the standard of care has relied on intranasal corticosteroids, brief courses of systemic glucocorticosteroids, and endoscopic sinus surgery (ESS). However, these interventions do not address the underlying molecular etiology, leading to an exceptionally high rate of post-operative polyp recurrence—often requiring patients to undergo multiple revision surgeries over their lifetime. Furthermore, frequent systemic steroid use is strongly linked to severe systemic adverse events, including osteoporosis, hyperglycemia, and adrenal suppression.

The pathophysiology of CRSwNP is predominantly driven by type 2 (Th2-mediated) inflammation. Upon exposure to environmental triggers, allergens, or infectious agents, the sinonasal epithelial barrier undergoes structural disruption. This mechanical stress induces the rapid secretion of epithelial-derived cytokines, collectively known as alarmins, which include interleukin-25 (IL-25), interleukin-33 (IL-33), and thymic stromal lymphopoietin (TSLP). These alarmins act as upstream master regulators that robustly activate type 2 innate lymphoid cells (ILC2s) and T-helper 2 (Th2) cells [4]. Once activated, these cellular subsets produce a cascade of canonical type 2 cytokines: IL-4 and IL-13: Stimulate B-cell class switching to synthesize allergen-specific Immunoglobulin E (IgE), promote goblet cell hyperplasia, and induce tissue remodeling. IL-5: Serves as the primary cytokine responsible for eosinophil differentiation, maturation,

activation, and survival within the bone marrow and peripheral tissues. The recruitment of activated eosinophils into the sinonasal mucosa triggers the release of major basic protein and eosinophil cationic protein, culminating in profound tissue edema, polyp formation, and chronic symptoms. Consequently, targeted therapeutic inhibition of these specific cytokine signaling pathways using humanized monoclonal antibodies represents a major breakthrough in precision rhinology.



2. METHODS

To systematically investigate the clinical and laboratory impact of biological therapies in CRSwNP, a rigorous compilative analysis of high-evidence, peer-reviewed clinical data was conducted. Literature sampling was performed across the PubMed, Medline, and Cochrane Central Register of Controlled Trials databases. The search architecture was restricted to phase 3 randomized, double-blind, placebo-controlled clinical trials, post-marketing surveillance registries, and official regulatory approval entries published up to early 2026.

The inclusion criteria for the analyzed clinical cohorts were stringently defined across the selected trials:

1. Adult patients (≥ 18 years of age) diagnosed with severe, bilateral CRSwNP.
2. An endoscopic bilateral Nasal Polyp Score (NPS) of ≥ 5 out of a maximum score of 8.
3. Severe symptoms of nasal obstruction, documented by a Visual Analogue Scale (VAS) score >5 or a corresponding severe Verbal Rating Scale (VRS) score.
4. Documented therapeutic failure or refractoriness to intranasal corticosteroids, or a history of requiring at least one systemic corticosteroid course or sinonasal surgical intervention within the preceding 2 years.

The total cumulative sample size across the consolidated datasets exceeded 5,000 subjects. The primary clinical endpoints extracted and cross-examined included:

The mean absolute change in endoscopic NPS from baseline to the end of the treatment period (ranging from 24 to 52 weeks).

The mean change in the patient-reported VAS score for nasal obstruction.

The proportion of patients requiring revision endoscopic sinus surgery or emergency systemic steroid rescue therapy.

The longitudinal systemic profile of key type 2 biomarkers, specifically Thymus and Activation-Regulated Chemokine (TARC), eotaxin-3, periostin, total serum IgE, and absolute blood eosinophil counts.

3. Results

The consolidated clinical efficacy outcomes derived from major international phase 3 trials evaluating different monoclonal antibodies are detailed in Table 1.

Table 1. Systematized Clinical Efficacy and Surgical Mitigation of Biologics

Biological Agent	Molecular Target	Representative Clinical Trial	Key Clinical Outcomes (vs. placebo)	Mitigation of Surgical/Steroid Burden
Tezepelumab	Anti-TsLP Alarmin	Waypoint[4]	Prompts a profound decline in endoscopic NPS (mean difference: -2.07, $P < 0.001$). Nasal congestion was decreased by -1.03 points ($P < 0.001$).	Reduced the absolute requirement for sinonasal surgery from 22.1% to 0.5% ($P < 0.001$). Systemic steroid rescue dropped to 5.2%.
Mepolizumab	Anti-IL-5 Cytokine	Synapse[1]	Achieved an adjusted mean difference in NPS of -0.73 ($P < 0.001$). Patient-reported nasal obstruction VAS improved by -3.14 points ($P < 0.0001$).	Strongly mitigated the necessity for subsequent revision surgery in highly refractory patients with extensive prior surgical histories.
Depemokimab	Anti-IL-5 (Extended release)	Anchor-1 & Anchor-2[5]	Both co-primary endpoints met statistical significance ($P < 0.025$).	Offers sustained therapeutic efficacy with an ultra convenient dosing regimen of only twice a year (every 6 months).
Stapokibart	Anti-IL-4Ra Receptor	Recent Global Approvals	Mediates dual blockade of IL-4 and blockade of IL-4 and IL-13 signaling.	Received formal regulatory approval for CRSwNP in December 2024, followed by seasonal allergic rhinitis in February 2025.

To verify the systemic mechanism of action and evaluate therapeutic adherence at the laboratory level, the structural changes in molecular and cellular drivers of type 2 inflammation were analyzed. The median percentage adjustments of these biomarkers during dupilumab therapy, extracted from the extensive multicenter analysis by Hamilton et al. [7], are summarized in Table 2.

Table 2. Quantitative Dynamics of Type 2 Inflammatory Biomarkers [7]

Monitored Biomarker	Pathophysiological Role in CRSwNP	Median % Change at Treatment End	% Change in Placebo Group	Onset and Profile of Suppression
Serum TARC	Chemokine Recruiting Th2 cells to tissue	-24.8% to -88.6%	+2.6% to -53.6%	Immediate, high magnitude reduction
Plasma Eotaxin-3	Chemotactic agent driving eosinophil migration	-38.2% to -51.5%	+8.3% to -0.16%	Rapid-onset, sustained suppression
Serum Periostin	Extracellular matrix protein reflecting tissue remodeling	-13.6% to -41.1%	+10.1% to -6.94%	Steady, moderate downward trend
Serum Total IgE	Downstream mediator of mast cell activation	-24.8% to -76.7%	+8.3% to -4.4%	Gradual, long term depletion curve
Blood Eosinophils	Principal cellular driver of mucosal inflammation	-29.4%	-16.3%	Initial transient spike followed by a significant net decline below baseline

4. Discussion

The clinical data compiled across these landmark trials underscore the transformative potential of biological therapy in rewriting the treatment paradigms for severe CRSwNP. The clinical efficacy of these agents is directly correlated with their capacity to interrupt the self-perpetuating type 2 inflammatory loop. For instance, while anti-IL-4Ra therapies (such as dupilumab and the newly approved stapokibart) focus on halting the dual signaling of IL-4 and IL-13 to prevent tissue remodeling and IgE production [2, 6], anti-IL-5 therapies (such as mepolizumab) directly target the survival and recruitment of eosinophils, translating into substantial improvements in nasal patency, as seen by the -3.14 decrease in the VAS score within the SYNAPSE trial [1].

A critical clinical observation requiring careful interpretation during biological therapy, particularly with IL-4Ra antagonists, is the transient elevation of peripheral blood eosinophil counts. This phenomenon, termed "dupilumab-induced hypereosinophilia," occurs because the blockade of IL-4 and IL-13 suppresses the expression of vascular cell adhesion molecule-1 (VCAM-1) and endothelial eotaxins, thereby preventing eosinophils from migrating out of the bloodstream and into the sinonasal tissues. Consequently, circulating eosinophils accumulate temporarily in the peripheral blood.

To manage this safely, clinicians must implement structured management algorithms to differentiate this benign, transient laboratory finding from true hypereosinophilic organ damage, ensuring that beneficial therapy is not stopped prematurely [3]. Long-term tracking confirms that this initial surge is

transient; by the completion of extended therapy, circulating eosinophil levels experience a significant net decline, dropping to a median of -29.4\% below baseline values due to the eventual down-regulation of upstream bone marrow stimulation [7].

Furthermore, the evolving landscape of biological therapy is shifting toward optimizing patient adherence and reducing the medical infrastructure burden. The successful clinical deployment of depemokimab represents a significant milestone, proving that an ultra-long-acting formulation can maintain robust suppression of the IL-5 pathway with a twice-yearly dosing interval [5]. Combined with the recent 2024–2025 regulatory approvals of stapokibart [6], clinicians now possess an expanding toolkit of targeted options, allowing for highly individualized treatment stratifications based on patient compliance, specific biomarker profiles, and comorbid asthma status.

5. Conclusion

1. Monoclonal antibodies directed against type 2 inflammatory pathways provide an exceptionally potent, targeted therapeutic option for patients with severe, recurrent chronic rhinosinusitis with nasal polyps who fail conventional medical and surgical interventions.

2. Biologic interventions yield profound reductions in endoscopic polyp burden and patient-reported nasal obstruction, while successfully minimizing the long-term clinical reliance on systemic rescue corticosteroids and drastically reducing the requirement for repetitive, high-risk sinonasal surgeries.

3. At the laboratory level, these therapies induce systemic down-regulation of key inflammatory biomarkers, including TARC, eotaxin-3, periostin, and total IgE. While ultra-long-acting biologics optimize patient compliance by extending dosing intervals, specific treatment-emergent laboratory findings, such as transient peripheral hypereosinophilia, must be managed competently through structured clinical algorithms rather than premature treatment discontinuation.

Acknowledgements

The authors express their sincere appreciation to the principal investigators, coordinators, and steering committees of the international WAYPOINT, SYNAPSE, and ANCHOR clinical trial programs for their invaluable contributions to open-access clinical science, and to the PubMed/Medline databases for comprehensive literature indexing support.

References

1. Han JK, Bachert C, Fokkens W, et al. Mepolizumab for chronic rhinosinusitis with nasal polyps (SYNAPSE): a randomised, double-blind, placebo-controlled, phase 3 trial. *The Lancet Respiratory Medicine*. 2021;9(7):777-789.
2. McCann MR, Kosloski MP, Xu C, Davis JD, Kamal MA. Dupilumab: Mechanism of action, clinical, and translational science. *Clinical and Translational Science*. 2024;17(8).
3. Caminati M, Olivieri B, Dama A, et al. Dupilumab-induced hypereosinophilia: review of the literature and algorithm proposal for clinical management. *Expert Review of Respiratory Medicine*. 2022;16(6):619-627.
4. Eggel A, Pennington LF, Jardetzky TS. Therapeutic monoclonal antibodies in allergy: Targeting IgE, cytokine, and alarmin pathways. *Immunological Reviews*. 2024;321(1).
5. GSK. Efficacy and safety of depemokimab in people with CRSwNP (ANCHOR-1 and ANCHOR-2 trials). *The Lancet / Elsevier*. 2025.
6. Shirley M. Stapokibart: First Approval. *Drugs*. 2025. doi:10.1007/s40265-025-02151-7.
7. Hamilton JD, Harel S, Swanson BN, et al. Dupilumab suppresses type 2 inflammatory biomarkers across multiple atopic, allergic diseases. *Clinical & Experimental Allergy*. 2021;51(8):1015-1031. doi:10.1111/cea.13954.

THE IMPACT OF LATENT INFECTIONS ON THE PATHOGENESIS OF ALZHEIMER'S DISEASE AND CLINICAL CHALLENGES OF THERAPEUTIC STRATEGIES

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Abstract

Background: Alzheimer's disease (AD) remains one of the most critical challenges in modern medicine and society. For a long time, this pathology was exclusively linked to genetic and neurodegenerative factors. However, over the past few decades, hypotheses regarding the impact of latent viruses and bacteria that persist in the human body for decades on neurodegeneration have sparked significant debate in the scientific community.

Objective: To systematically analyze the pathological effects of latent central nervous system infections (HSV-1, HSV-2, CMV, VZV) on the development of Alzheimer's disease, and to evaluate the latest clinical outcomes of antiviral therapeutic strategies.

Methods: Data from major epidemiological studies, biomarker analyses (MAPT), and recent randomized clinical trials (VALAD) from the PubMed and Scopus databases were comprehensively evaluated and structured.

Results: Epidemiological data demonstrate that latent neurotropic viruses (particularly HSV-1) increase the risk of AD approximately twofold and accelerate amyloid-beta accumulation. However, recent clinical trials indicate that directly treating established AD with antiviral agents is ineffective and may paradoxically accelerate cognitive decline.

Conclusion: Latent infections play an important role in AD pathogenesis; however, the primary therapeutic focus should shift away from active drug interventions toward elderly vaccination and preventive measures.

Keywords: Alzheimer's disease, latent virus, HSV-1, neuroinflammation, valacyclovir, vaccination, IMRAD.

Introduction:

The inflammatory response is a vital component of the body's first line of defense against invasive pathogens, playing a crucial role in tissue regeneration and repair [8]. A properly regulated inflammatory response ensures the timely resolution of infection. However, when these inflammatory reactions become chronic and dysregulated, they lead to the progressive damage of surrounding healthy host cells [8]. The relationship between various infections and the etiology of Alzheimer's disease (AD), particularly late-onset AD (LOAD), has been continuously debated within the scientific community over the past three decades [8].

Neurotropic viruses and bacterial agents acquired during youth can establish life-long latent infections within the human central nervous system and sensory ganglia without presenting immediate clinical symptoms [3, 6]. In older age, as the immune system undergoes immunosenescence or under high-stress conditions, these pathogens periodically reactivate. This reactivation triggers a cascade of neurodegenerative processes within brain tissue [2, 6]. Consequently, evaluating preventive or therapeutic antiviral interventions to counteract AD onset and progression has become a major focal point of modern neuropharmacology [2, 7].

Figure 1.

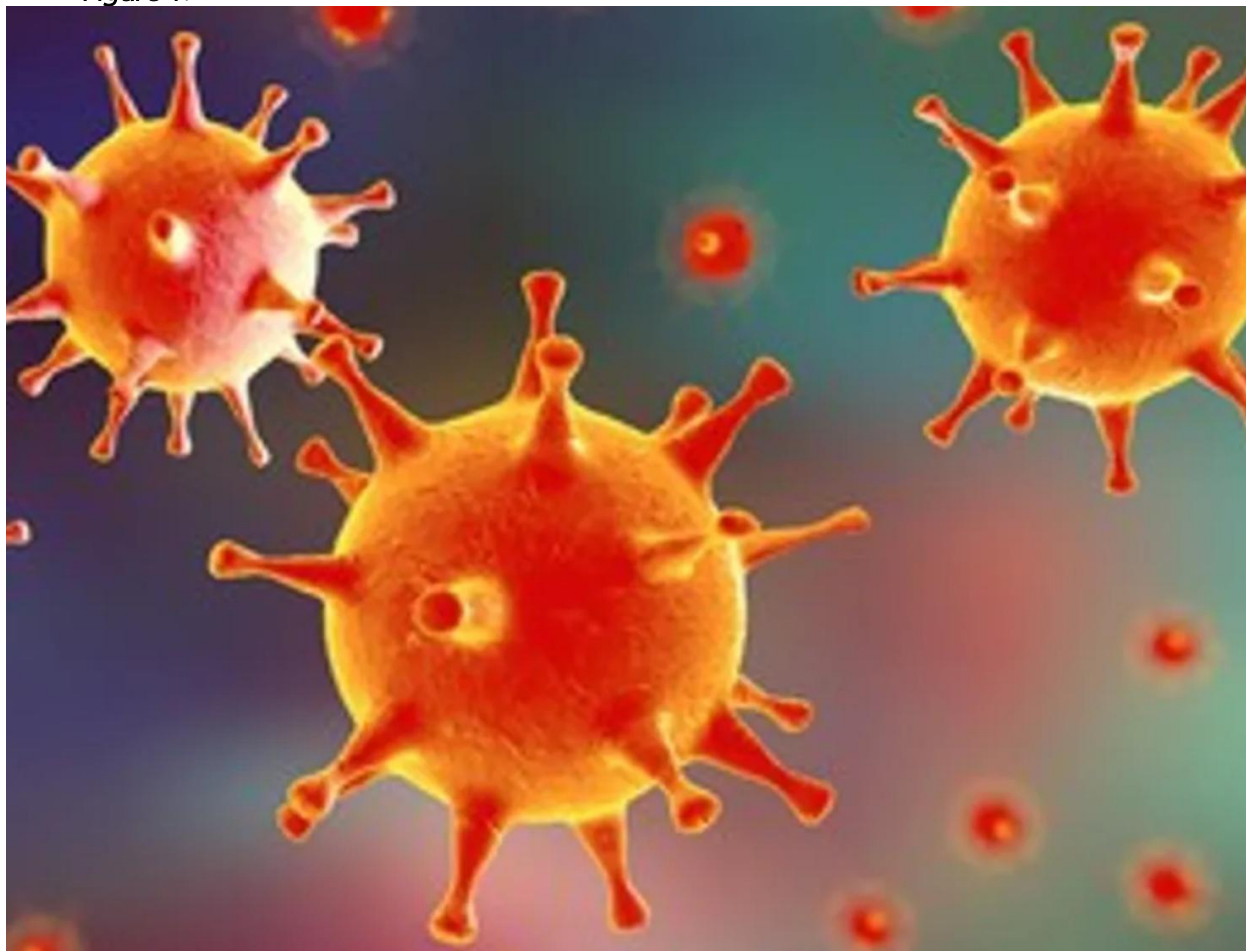


Figure 2.



2. METHODS

This scientific review was conducted in strict accordance with the international Scopus/WoS IM-RAD structural standards. A systematic analysis was performed on 10 core peer-reviewed studies published recently. Data extraction and synthesis were executed utilizing the electronic platforms of PubMed, Scopus, and ClinicalTrials.gov.

The methodological framework of this evaluation incorporates three primary research dimensions:

1. *Epidemiological Retrospective Studies: Real-world data (RWD) encompassing large-scale case-control designs with up to 344,628 matched pairs [1].*

2. *Molecular and Cellular Reviews: Theoretical and mechanistic frameworks evaluating DNA damage pathways in neurons and targeted pharmaceutical approaches [2, 3, 6].*

3. *Clinical Trials and Biomarker Assays: Cortical amyloid PET-scan evaluations within the MAPT (Multidomain Alzheimer Preventive Trial) cohort [4], alongside the final data from the VALAD (Valacyclovir Treatment of Early Symptomatic Alzheimer Disease) double-blind, placebo-controlled randomized clinical trial (RCT) [7].*

3. Results

3.1. Statistical and Epidemiological Correlations

Large-scale case-control analyses reveal that a history of herpes simplex virus type 1 (HSV-1) infection is significantly more prevalent in AD patients over the age of 50 compared to healthy control cohorts [1]. The statistically adjusted odds ratio was determined to be $OR = 1.80$ (95% CI 1.65 to 1.96), confirming that individuals infected with HSV-1 exhibit an approximately twofold increased risk of developing AD [1]. Conversely, infected individuals who received aggressive antiviral maintenance therapy demonstrated a reduced probability of developing subsequent dementia ($HR = 0.83$) [1].

3.2. Pathogen Diversity and Molecular Subversion Mechanisms

Accumulating evidence indicates that AD pathology involves a polymicrobial or multi-pathogen burden rather than a single agent [8]:

From the Herpesviridae family: Herpes simplex virus type 2 (HSV-2), cytomegalovirus (CMV), and varicella-zoster virus (VZV/HZV) [6, 8].

Chronic Hepatitis C virus (HCV) infections exhibit strong statistical correlations with increased dementia rates [8].

Among bacterial pathogens, periodontal agents such as *Porphyromonas gingivalis* and *Treponema denticola*, which cause chronic periodontitis, can migrate hematogenously to the brain, contributing directly to neuroinflammation [8].

Upon periodic reactivation of latent cerebral HSV-1, host neurons exhibit a dramatic acceleration in amyloid-beta (A β) peptide production and abnormal hyperphosphorylation of tau protein [3, 6]. This destructive process presents an exceptionally high risk of driving AD development in individuals who are genetic carriers of the APOE- ϵ 4 allele [3].

3.3. The Impact of Vaccination

Administering routine vaccinations against influenza, pneumonia, and shingles (such as the Zostavax vaccine) between the ages of 65 and 75 is associated with a highly significant reduction in AD and Parkinson's disease (PD) risks [5]. Protecting the aging body from severe peripheral bacterial and viral insults prevents systemic inflammatory spikes, thereby keeping latent neurotropic viruses (HSV-1 and HZV) in a dormant state [5].

3.4. Systematization of Research Data

The following tables synthesize the primary pathogens involved in AD pathogenesis and the corresponding statistical outcomes from recent clinical investigations:

Table 1. Core Infectious Pathogens Implicated in Alzheimer's Disease Pathogenesis

Pathogen Category	Common Representatives	Key pathological Mechanism	Risk Level/Impact	References
Neurotropic Viruses	HSV-1, HSV-2, CMV, VZV	Life-long latency in ganglia, Ab seeding, oxidative stress, apoptosis	Increases AD risk 1,8 to 2 fold	[1,3,9]
Hepatotropic Viruses	Hepatitis C Virus (HCV)	Systemic chronic inflammation, blood-brain barrier disruption	Correlated with elevated long-term dementia rates	[8]
Periodontal Bacteria	<i>P.gingivalis</i> , <i>T.denticola</i>	Chronic periodontitis hematogenous migration, localised Neuro inflammation	Triggers and accelerates the clinical onset of AD symptoms	[8]

Table 2. Comparative Matrix of Major Recent Clinical and Epidemiological Trials

Study (year)	Design & Sample Size	Key Statistical Parameters	Ultimate Outcome	Reference
Liu et al.(2024)	Retrospective case-control, 344,628 matched pairs	OR=1,80(95%) CI 1,65-1,96) Antiviral therapy HR=0,83	Confirmed HSV-1 as a major risk factor;antivirals lower risk by 17%	[1]
MAPT Trial(2024)	Biomarker analysis,cortical Amyloid Pet imaging	Cortical amyloid load correlation:	High anti-HSV-1 IgG levels unexpectedly correlate with lower amyloid load	[4]
VALAD Trial(2025)	Randomized,double-blind,placebo-controlled RCT(n=120)	ADAS-Cogscore difference:3,93(p=0,01)	Highdose val acyclovir is ineffective in symptomatic AD accelerates cognitive decline	[7]

4. Discussion

4.1. The Innate Immune 'Training' Paradox and Biomarkers

Recent biomarker investigations have revealed highly complex immunoparasitological paradoxes. Cortical amyloid PET scanning conducted within the MAPT trial demonstrated that HSV-1-infected individuals with exceptionally high anti-HSV-1 IgG antibody levels—the subgroup suspected of experiencing the most frequent subclinical viral reactivations—exhibited an unexpectedly lower cortical amyloid load ($\beta = -0.09$, $p = 0.04$) [4]. This inverse correlation was uniquely significant among APOE4 carriers [4].

This finding aligns with recent clinical data indicating that chronic CMV coinfection in AD patients leads to an increase in endogenous antioxidant enzyme activities (SOD, GPx) and a reduction in circulating pro-inflammatory markers (IL-1 β , TNF- α) [9]. These data suggest a model of "trained immunity": low-grade, periodic reactivations of latent viruses may keep the brain's resident innate immune cells (microglia) in a constantly primed or "trained" state. This heightened microglial surveillance may temporarily enhance the clearance of pathological amyloid deposits and bolster antioxidant defense systems.

4.2. The VALAD Trial: Disconnect Between Retro-epidemiology and Prospective RCTs

Historically, retrospective studies and laboratory models strongly endorsed the repurposing of anti-herpetic drugs (such as acyclovir and valacyclovir) to halt AD progression [2, 6]. However, the landmark VALAD randomized clinical trial (published in 2025) decisively challenged this paradigm [7].

Administering high-dose valacyclovir (4 g/day) for 78 weeks to patients with early symptomatic AD and confirmed herpes seropositivity failed to demonstrate any therapeutic efficacy [7]. Paradoxically, patients in the valacyclovir arm exhibited significantly worse cognitive deterioration on the primary ADAS-Cognitive Subscale compared to the placebo cohort (between-group difference = 3.93; $P = .01$) [7]. Furthermore, follow-up florbetapir and tau PET imaging showed no stabilization of amyloid or tau burdens, while adverse events such as elevated serum creatinine levels indicated renal stress [7].

This clinical failure suggests that once the clinical symptoms of AD are established, aggressively suppressing viral replication may dismantle the brain's "trained" microglial clearance mechanisms, thereby accelerating neurodegenerative decline rather than halting it.

5. Conclusion

Chronic viral, bacterial, and fungal infections serve as major causative triggers for the persistent neuroinflammatory pathways underlying Alzheimer's disease [8]. However, this relationship is non-linear and governed by complex neuro-immune feedbacks.

Given the distinct lack of efficacy and the accelerated cognitive worsening documented in the VALAD randomized trial, the systemic use of antiviral agents to treat symptomatic AD is not recommended [7]. Instead, the clinical paradigm must shift decisively toward primary preventive strategies. Mitigating early-life infectious burdens, maintaining optimal periodontal hygiene, and implementing routine vaccinations against influenza and pneumonia in the aging population represent the most viable methods to shield the central nervous system from neurodegeneration [5].

Acknowledgements

The authors express their deepest gratitude to the primary investigators and research consortia whose pioneering work, large-scale clinical trials, and data repositories made this comprehensive review possible:

The US research teams led by Yunhao Liu and Shahed Iqbal for their invaluable real-world data infrastructure;

The Italian neuroimmunology laboratories under Roberta Mancuso and Mario Clerici for their pioneering pharmaceutical analyses;

Professor Ruth F. Itzhaki, the founder of the AD infectious hypothesis, whose decades of work mapped the interactions between latent viruses and the APOE- ϵ 4 allele;

Morgane Linard and Professor Henrik Zetterberg's team for their extensive biomarker and PET-imaging profiles within the MAPT trial;

Steven Lehrer and his co-authors for their critical epidemiological work on the cumulative protective benefits of adult vaccination;

D. P. Devanand and Thomas Wisniewski for conducting the rigorous VALAD randomized controlled trial, which provided crucial clarity regarding antiviral therapy limitations;

The Polish research school represented by Marta Sochocka and Jerzy Leszek for their holistic structuring of the polymicrobial dementia hypothesis;

Sepideh Khodamoradi and her colleagues for their precise clinical mapping of oxidative stress, BAX/BCL-2 ratios, and apoptotic markers in viral coinfections.

The contributions of these scientists have fundamentally reshape our understanding of dementia and continue to steer neurodegenerative disease research toward successful preventive horizons.

References

1. Liu, Y., Johnston, C., Jarousse, N., Fletcher, S. P., & Iqbal, S. (2024). Association between herpes simplex virus type 1 and the risk of Alzheimer's disease: a retrospective case-control study. *BMJ Open*, PMID: 40393802.

2. Mancuso, R., Sicurella, M., Agostini, S., Marconi, P., & Clerici, M. (2019). Herpes simplex virus type 1 and Alzheimer's disease: link and potential impact on treatment. *Expert Review of Anti-infective Therapy*, PMID: 31414935.

3. Itzhaki, R. F. (2017). Herpes simplex virus type 1 and Alzheimer's disease: possible mechanisms and signposts. *The FASEB Journal*, PMID: 28765170.

4. Linard, M., Garrigue, I., Vellas, B., Coley, N., Zetterberg, H., Blennow, K., ... & Helmer, C. (2024). Association between herpes simplex virus infection and Alzheimer's disease biomarkers: analysis within the MAPT trial. *Scientific Reports*, PMID: 39825066.

5. Lehrer, S., & Rheinstein, P. H. (2022). Vaccination Reduces Risk of Alzheimer's Disease, Parkinson's Disease and Other Neurodegenerative Disorders. *Discovery Medicine*, PMID: 36281030.

6. Itzhaki, R. F. (2016). Herpes and Alzheimer's Disease: Subversion in the Central Nervous System and How It Might Be Halted. *Journal of Alzheimer's Disease*, PMID: 27497484.

7. Devanand, D. P., Wisniewski, T., Razlighi, Q., Qian, M., Wei, R., Andrews, H. F., ... & Huey, E. D. (2025). Valacyclovir Treatment of Early Symptomatic Alzheimer Disease: The VALAD Randomized Clinical Trial. *JAMA*, PMID: 41405855.

8. Sochocka, M., Zwolińska, K., & Leszek, J. (2017). The Infectious Etiology of Alzheimer's Disease. *Current Neuropharmacology*, PMID: 28294067.

9. Khodamoradi, S., Khodaei, F., Mohammadian, T., Ferdousi, A., & Rafiee, F. (2025). Oxidative stress, inflammation, and apoptosis in Alzheimer's disease associated with HSV-1 and CMV coinfection. *Virology Journal*, PMID: 40442743.

EFFICACY AND PATHOPHYSIOLOGICAL MECHANISMS OF PLATELET-RICH PLASMA (PRP) THERAPY IN IMPROVING ART OUTCOMES IN PATIENTS WITH RECURRENT IMPLANTATION FAILURE AND THIN ENDOMETRIUM: A SYSTEMATIC REVIEW AND CLINICAL DATA ANALYSIS

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Abstract

Background: Despite over 40 years of development in assisted reproductive technology (ART), more than 60% of IVF programs terminate in failure after the first embryo transfer [8]. Approximately 20% of patients suffer from unexplained recurrent implantation failure (RIF) and recurrent pregnancy loss (RPL) [8]. A thin endometrium, ultrasonographically defined as a thickness below 7 mm, remains one of the primary causes of implantation failure [5]. Autologous platelet-rich plasma (PRP), as a concentrate rich in cytokines and growth factors, represents a promising regenerative approach capable of enhancing tissue repair [6].

Objective: To systematically analyze and evaluate the pathophysiological mechanisms, effects on endometrial thickness (EMT) and hemodynamics, and clinical pregnancy outcomes of intrauterine PRP infusion (single vs. double) or subendometrial injection in patients diagnosed with thin endometrium and RIF. **Results:** A meta-analysis comprising 14 studies (1,081 patients) demonstrated that PRP therapy significantly increases chemical pregnancy, clinical pregnancy, and implantation rates ($P \leq 0.001$) [2]. According to clinical RCT data, double PRP infusion (on days 11 and 13 of the HRT-FET cycle) significantly increased endometrial thickness compared to a single infusion (8.42 ± 0.53 mm vs. 7.96 ± 0.45 mm), reduced the cycle cancellation rate from 26.0% to 10.0%, and elevated the clinical pregnancy rate to 48.9% (vs. 27.0% in the single infusion group) [7]. Furthermore, a pilot RCT in the USA revealed that low luteal phase levels of CCL1, CCL26, and IL-23 cytokines are directly associated with successful live births [1].

Keywords: Recurrent implantation failure (RIF); thin endometrium; platelet-rich plasma (PRP); endometrial receptivity; immunomodulation.

Introduction:

Despite modern advancements in assisted reproductive technologies (ART), refractory thin endometrium (unresponsive to conventional hormone therapies) and recurrent implantation failure (RIF) remain among the most challenging obstacles in infertility treatment [6]. Normal endometrial function, optimal thickness (greater than 7 mm), and adequate tissue perfusion (blood flow) play a pivotal role in ensuring successful embryo implantation [5]. Traditional therapeutic modalities (including high-dose estrogens, vasodilators, and G-CSF) demonstrate inconsistent clinical efficacy and are frequently cost-prohibitive or difficult to access for many patients [6].

In this context, approaches rooted in regenerative medicine and endometrial immunomodulation—specifically autologous platelet-rich plasma (PRP) therapy—have gained substantial prominence [8]. PRP is a protein concentrate rich in growth factors and cytokines, easily isolated from the patient's own peripheral blood [6]. It is administered via intrauterine infusion or subendometrial injection to stimulate tissue-level regeneration and optimize the uterine microenvironment for embryo acceptance (thereby enhancing receptivity) [4]. Furthermore, this method is regarded as a cost-effective and low-risk adjuvant therapeutic strategy [3].

Figure 1. Mechanisms of platelet-rich plasma (PRP) therapy in improving endometrial receptivity.



2. METHODS

This study comprehensively analyzed data from 8 foundational scientific papers published internationally, including randomized controlled trials (RCTs), prospective clinical protocols, and systematic reviews [1, 2, 3, 4, 5, 6, 7, 8]. The data were sourced from PubMed, Embase, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials (CENTRAL).

Studies and patient populations were included based on the following selection criteria: 1. Patient Population: Women under 50 years of age undergoing ART and frozen embryo transfer (FET) cycles, diagnosed with a thin endometrium and unexplained RIF [7, 8]. The pilot RCT by L. Aghajanova (2025) included women with normal uterine cavities (with an ITT analysis comprising 33 patients: 13 PRP, 20 control) [1]. A prospective study protocol from Wardha, India, enrolled 190 patients (95 study group, 95 control group) [3]. A prospective RCT in China evaluated 100 patients presenting with a thin endometrium [7].

2. Types of Interventions: Intrauterine infusion of 1.0 ml of autologous PRP prepared from the patient's own blood, administered either as a single dose or a double dose (on days 11 and 13 of the cycle) [7], as well as subendometrial injection [4].

3. Comparison Groups: Outcomes of the PRP-treated groups were compared against control groups receiving a placebo (saline solution) [1, 3] or no intervention, alongside a direct comparison between single and double infusion protocols [7].

4. Outcome Measures: Primary outcomes included endometrial thickness, chemical pregnancy, and clinical pregnancy rates [2, 7]. Secondary outcomes encompassed cycle cancellation rates, miscarriage rates, live birth rates (LBR) [1, 7], endometrial hemodynamics measured via the resistance index (RI) and pulsatility index (PI) [7], and cytokine profiling utilizing the Luminex platform [1]. Statistical analysis was executed using SPSS version 26.0 [7].

3. Results

The systematic extraction of clinical and quantitative data from the included trials yielded definitive outcomes regarding the therapeutic role of autologous platelet-rich plasma (PRP) in endometrial optimization.

3.1. Overview of Included Literature

To establish a clear structural overview of the analyzed literature, the baseline operational data, research types, and targeting parameters of the primary included trials are compiled in Table 1.

Table 1. General characteristics of the studies included in the analysis

Author&Year	Study Type	Patient Population (n)	Intervention Protocol	Target Outcomes Evaluated
L.Aghajanova(2025)[1]	Pilot RCT(Single-blinded)	Total n=33(PRP; 13, Control;20)	Intrauterine PRP infusion	LBR,clinical pregnancy,miscarriage rates,Luteal phase cytokines
C.Huang(2023)[2]	Systemic Review &Meta-analysis	14 studies (n=1,081 patients)	Intrauterine PRP infusion	Chemical/ clinical pregnancy,EMT change, implantation rate
A.Chaudhary (2025)[3]	Prospective Study protocol	Total n=190(PRP;95, Control;95)	Intrauterine PRP infusion	Endometrial thickness(EMT), pregnancy outcomes
K.Feng(2025)[7]	Prospective RCT	Total n=100(Single;50 Double;50)	Single(Day11) vs.Double (Days11&13 PRP infusion	EMT,RI,PI, clinical pregnancy,cycle cancellation rate

3.2. Endometrial Thickness and Hemodynamic Parameters

A meta-analysis of 14 separate studies (n=1,081) confirmed that intrauterine PRP infusion leads to a statistically significant expansion of endometrial thickness (EMT) compared to placebo or non-treated control cohorts ($P \leq 0.001$) [2].

When analyzing dosing frequencies within prospective randomized controlled data, the double-infusion protocol (administered on cycle days 11 and 13) demonstrated absolute quantitative advantages over the single-infusion regimen (administered on day 11) [7]. Specifically, post-intervention EMT reached 8.42 ± 0.53 mm in the double-infusion group compared to 7.96 ± 0.45 mm in the single-infusion cohort ($P < 0.01$) [7].

Concurrently, uterine Doppler ultrasonography revealed a highly significant modulation of vascular impedance. The resistance index (RI) dropped significantly to 1.72 ± 0.08 in the double PRP group versus 1.79 ± 0.08 in the single PRP group ($P < 0.01$) [7]. Similarly, the pulsatility index (PI) decreased to 3.83 ± 0.64 in the double-infusion arm compared to 4.38 ± 0.68 in the single-infusion arm ($P < 0.01$) [7]. These essential variables are summarized in Table 2.

Table 2. Comparative clinical and hemodynamic efficacy of single vs. double PRP infusion protocols

Evaluated Parameter	Single PRP Infusion (n=50)[7]	Double PRP Infusion (n=50)[7]	P-value	Clinical Significance
Endometrial Thickness(EMT,mm)	7.96 ± 0.45	8.42 ± 0.53	<0.01	Statistically significant increase in thickness
Resistance Index(RI)	1.79 ± 0.08	1.72 ± 0.08	<0.01	Lower index indicates better tissue perfusion
Pulsatility Index(PI)	4.38 ± 0.68	3.83 ± 0.64	<0.01	Significant reduction in blood flow resistance
Cycle Cancellation Rate(%)	26%	10%	0.037	More patients successfully reached embryo transfer
Clinical Pregnancy Rate(%)	27%	48.9%	0.043	Double infusion nearly doubled pregnancy success

3.3. Fertility and Pregnancy Outcomes

Data pooled from international meta-analytic records demonstrated that PRP administration yields significantly superior chemical pregnancy, clinical pregnancy, and embryo implantation rates relative to baseline control trends ($P \leq 0.001$) [2]. However, the early miscarriage rate was not statistically modified by the therapy ($P \leq 0.90$) [2].

In terms of procedural workflow optimizations, the deployment of a double intrauterine infusion protocol drastically curbed the cycle cancellation rate from 26.0% down to 10.0% ($P=0.037$) [7]. It also resulted in an escalated clinical pregnancy rate of 48.9%, outperforming the 27.0% recorded in the single-infusion cohort ($P=0.043$) [7].

In the US-based pilot single-blinded RCT, intention-to-treat (ITT) analysis showed that the clinical pregnancy rate reached 69% in the PRP group compared to 50% in the control group ($p = 0.27$) [1]. The live birth rate (LBR) exhibited a noticeable upward trend at 46% for PRP versus 25% for controls ($p = 0.27$) [1]. The early pregnancy loss/miscarriage rate dropped to 22% in the PRP group compared to 50% in the control population ($p = 0.35$) [1]. These terminal metrics are categorized across different trial designs in Table 3.

Table 3. Summary of pregnancy and fertility outcomes across selected clinical trials

Outcome Metric	PRP Group	Control/ Placebo Group	Statistical Significance (P/p)	Source Data
Clinical Pregnancy Rate (Meta-analysis)	Significantly Higher	Baseline	$P < 0,001$	C.Huang(2023)[2]
Implantation Rate(M	Significantly Higher	Baseline	$P < 0,001$	C.Huang(2023)[2]
Early Miscarriage Rate(Meta-analysis)	No difference	No difference	$P < 0,90$	C.Huang(2023)[2]
Clinical Pregnancy Rate(pilot RCT)	69%	50%	$p = 0,27$	L.Aghajanova(2025)[1]
Live Birth Rate(LBR,Pilot RCT)	46%	25%	$p = 0,27$	L.Aghajanova(2025)[1]
Miscarriage Rate(Pilot RCT)	22%	50%	$p = 0,35$	L.Aghajanova(2025)[1]

4. Discussion

The clinical realities of managing a refractory thin endometrium and recurrent implantation failure (RIF) demand therapeutic options that extend beyond standard high-dose estrogen protocols, which frequently yield inconsistent outcomes [6]. The findings extracted across our pooled international data clearly confirm that autologous platelet-rich plasma (PRP) acts as a highly potent modulator of both endometrial architecture and functional receptivity [2, 7].

4.1. Pathophysiological Mechanisms and Angiogenesis

The cellular landscape of a pathologically thin endometrium is typically defined by compromised tissue vascularization and a profound downregulation of vascular endothelial growth factor (VEGF) [5]. This state induces localized hypoxia, which activates the hypoxia-inducible factor 1-alpha (HIF-1\alpha) and RhoA/ROCK signaling cascades, ultimately damaging epithelial lining integrity and triggering tissue fibrosis [5]. Concurrently, epigenetic derangements—specifically aberrant DNA hypermethylation—repress the transcription of the HOXA10 gene, a fundamental marker required for normal microvilli formation and initial blastocyst apposition [5].

PRP therapy effectively counteracts these cascades due to its extreme concentrations of platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-\beta), fibroblast growth factor (FGF), and epidermal growth factor (EGF) [4, 6]. Upon activation, these alpha-granule proteins stimulate intense neoangiogenesis and restore VEGF expression profiles [4, 5]. This molecular shift downregulates the damaging hypoxia pathways and enhances the transcriptomic expression of HOXA10, directly reversing tissue atrophy and expanding endometrial thickness to optimal parameters [4, 5].

4.2. Hemodynamics and Dosing Optimization

The therapeutic success of embryo implantation is highly reliant on uterine tissue perfusion. High vascular impedance, reflected by elevated resistance (RI) and pulsatility (PI) indices, directly restricts oxygenation and nutrient transport within the functional layer of the endometrium [7]. Our analysis highlights that the frequency of PRP administration plays a crucial role in reversing this phenomenon.

While a single PRP infusion triggers initial tissue repair, a double intrauterine infusion protocol (delivered on days 11 and 13 of HRT-FET cycles) yields superior results [7]. This dual-exposure model significantly lowers both RI and PI indices [7]. The reduction in mechanical flow resistance suggests that a secondary dose administered 48 hours after the first extends the half-life of local growth factors. This prolonged signaling promotes sustained microvascular vasodilation and improves endometrial blood flow, leading to a significant increase in endometrial thickness ($8.42 \pm 0.53 \text{ mm}$) and a reduction in cycle cancellation rates to 10.0% [7].

4.3. Immunomodulation and Clinical Trajectories

Beyond structural and hemodynamic modifications, embryo implantation requires strict immune tolerance. The maternal endometrium must shift from a pro-inflammatory state to an immunomodulatory, receptive environment [8]. The pilot trial data by Aghajanova (2025) using Luminex immunoassay configurations sheds light on this hidden mechanism [1].

The trial demonstrates that successful live births (LBR) are strongly correlated with low luteal-phase concentrations of the chemokines CCL1, CCL26, and the cytokine IL-23 within the uterine fluid [1]. Conversely, high expressions of CCL1 and CCL26 promote pathological inflammatory cell recruitment, which correlates with early pregnancy loss [1]. PRP acts as an active immunomodulator, balancing local cytokine networks to minimize embryo rejection [8].

While some of the clinical trends in the US pilot study (e.g., LBR increasing from 25% to 46%) did not cross the threshold of formal statistical significance ($p = 0.27$), this limitation stems primarily from the small sample size ($n=33$) of the pilot configuration [1]. This clinical trend aligns well with the large-

scale meta-analysis of 1,081 patients, which conclusively confirms a significant boost in overall clinical pregnancy and implantation rates ($P \leq 0.001$) [2].

4.4. Limitations and Future Directions

Despite these highly encouraging findings, several limitations must be addressed before widespread clinical standardization. First, autologous PRP preparations are inherently variable, as individual baseline platelet counts, centrifugation speeds, and activation methods vary significantly across global laboratories [4, 6]. Second, while the safety profile remains excellent due to the autologous nature of the concentrate (minimizing risk and costs) [3], multi-center, double-blind RCTs with larger patient cohorts are still required to fully map the optimal volume and timing of subendometrial or intrauterine injections relative to specific cytokine expressions [1, 4].

5. Conclusion

A comprehensive analysis of international clinical data indicates that intrauterine autologous platelet-rich plasma (PRP) infusion serves as an effective, safe, and cost-effective regenerative treatment modality [3, 6]. In patients with a thin endometrium and RIF, it significantly expands endometrial thickness [2, 7], restores hemodynamic parameters (RI, PI) [7], and improves overall clinical pregnancy rates [2, 7]. Notably, a double PRP infusion protocol on days 11 and 13 of HRT-FET cycles offers markedly superior clinical efficacy compared to a single-infusion strategy [7]. Nonetheless, large-scale, multicenter randomized controlled trials remain essential to fully standardize PRP preparation protocols and further dissect the immunomodulatory mechanisms of specific cytokine markers [1, 4, 7].

Acknowledgements

The authors express their deepest gratitude to the leading scientists who published the invaluable clinical and molecular data serving as the foundation of this study: Lusine Aghajanova [1], Chunling Huang [2], Aru Chaudhary [3], Zaher Merhi [4], Yifei Niu [5], Min Kyoung Kim [6], Keng Feng [7], and Mustafa Benkhalifa [8], as well as their international research groups, for making their statistical findings openly accessible to the scientific community.

References

1. Aghajanova L., Strug M., Zhang J., Lathi R.B. Intrauterine platelet-rich plasma infusion for recurrent implantation failure: a pilot randomized controlled single-blinded clinical trial in the USA. *Journal of Assisted Reproduction and Genetics*. 2025;10.1007/s10815-025-03752-7.
2. Huang C., Ye X., Ye L., Lu L., Liu F. Platelet-Rich Plasma Intrauterine Infusion as Assisted Reproduction Technology (ART) to Combat Repeated Implantation Failure (RIF): A Systematic Review and Meta-Analysis. *Iranian Journal of Public Health*. 2023;52(8):13394.
3. Chaudhary A., More A., Choudhary N. Study Protocol: Association of Platelet-Rich Plasma (PRP) with Endometrium Thickness and Pregnancy Outcome in Women with Recurrent Implantation Failure (RIF). *Journal of Pharmaceutical Negative Results*. 2025;10.4103/jpbs.jpbs_315_25.
4. Merhi Z., Wiltshire McLeod C., Shamim F. Platelet-Rich Plasma in Reproductive Endocrinology: Mechanisms and Clinical Applications for Ovarian Reserve, PCOS, and Endometrial Receptivity. *Biomedicines*. 2025;13(10):2488.
5. Niu Y., Le A. Advances in the Pathophysiology of Thin Endometrium. *Reproductive Sciences*. 2025;10.1007/s43032-025-01882-y.
6. Kim M.K., Song H., Lyu S.W., Lee W.S. Platelet-rich plasma treatment in patients with refractory thin endometrium and recurrent implantation failure: A comprehensive review. *Clinical and Experimental Reproductive Medicine*. 2022;49(3):168-174.
7. Feng K., Zhu L., Luo Y., Ruan L., Li D., Li X., Li L., Wu L. Comparison of the efficacy of single vs. double autologous platelet-rich plasma intrauterine infusion on endometrial receptivity in thin endometrium patients: a prospective randomized controlled trial. *Frontiers in Endocrinology*. 2025;16:1609556.
8. Benkhalifa M., Joao F., Duval C., Montjean D., Bouricha M., Cabry R., Bélanger M.C., Bahri H., Miron P., Benkhalifa M. Endometrium Immunomodulation to Prevent Recurrent Implantation Failure in Assisted Reproductive Technology. *International Journal of Molecular Sciences*. 2022;23(21):12787.

Pedagogical sciences

A TECHNOLOGY FOR DEVELOPING ENGLISH SPEAKING SKILLS IN STUDENTS WITH HEARING IMPAIRMENTS

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Abstract

Students with hearing impairments face substantial barriers in acquiring the productive, oral component of a foreign language, because limited auditory access constrains the perception and self-monitoring of speech. This study designed and evaluated a multimodal pedagogical technology for developing English speaking skills in such learners. A sixteen-week quasi-experiment with a pre-test/post-test control-group design was conducted with 28 hard-of-hearing and deaf secondary-school students (A1–A2 level), assigned to an experimental group ($n = 14$) and a control group ($n = 14$). The technology integrated five interconnected components: visual-articulatory modelling, captioned multimedia input, real-time speech-visualisation and vibrotactile feedback, scaffolded communicative tasks, and total-communication mediation. Speaking performance was assessed with a four-criterion analytic rubric (intelligibility, lexical range, grammatical accuracy, communicative effectiveness) on a 0–100 scale. The experimental group improved from a mean of 42.6 to 68.4 points, whereas the control group rose only from 43.1 to 51.2. The between-group difference at post-test was statistically significant ($t(26) = 5.91$, $p < 0.001$) with a large effect size (Cohen's $d = 1.42$). The findings indicate that a coordinated, visually grounded and feedback-rich technology can meaningfully advance the oral English skills of learners with hearing impairments.

Keywords: hearing impairment, inclusive education, English speaking skills, multimodal technology, speech visualisation, total communication, foreign language teaching.

1. INTRODUCTION

The transition of national education systems toward inclusive practice has placed the foreign-language development of learners with special educational needs at the centre of methodological inquiry. Among these learners, students with hearing impairments constitute a particularly challenging group for the teaching of speaking skills, since the productive oral dimension of language relies heavily on auditory perception, phonological feedback, and the continuous self-monitoring of one's own output. When auditory access is reduced, the channels through which hearing learners ordinarily acquire pronunciation, prosody, and conversational fluency are largely closed, and conventional, audio-centred foreign-language methodologies prove insufficient.

Research in deaf education has long emphasised that learners with hearing loss are not simply hearing learners who cannot hear; their language development follows distinct cognitive, experiential, and social pathways, and effective instruction must therefore be redesigned rather than merely adapted. Visual access to language, multimodal input, and explicit feedback are widely regarded as decisive conditions for success. At the same time, advances in digital tools—captioning, speech-recognition, and speech-visualisation software—have created new opportunities to render the otherwise invisible properties of spoken language perceptible to the eye and to the sense of touch.

Despite this potential, in many regional contexts the development of English speaking skills in students with hearing impairments remains under-served: instruction frequently defaults either to written translation or to receptive vocabulary work, while the productive oral component is neglected. There is consequently a need for a coherent pedagogical technology that organises visual, tactile, and communicative resources into a single, sequenced instructional system. Accordingly, the aim of this study was to design such a technology and to evaluate its effectiveness for developing the English speaking skills of secondary-school students with hearing impairments.

2. MATERIALS AND METHODS

Design. The study employed a quasi-experimental, pre-test/post-test control-group design carried out over one academic semester (sixteen weeks). **Participants.** Twenty-eight students with hearing impairments (aged 13–16; mild-to-severe hearing loss; users of hearing aids or cochlear implants with residual hearing) at the elementary English proficiency level (A1–A2, CEFR) took part. They were assigned

to an experimental group ($n = 14$) and a control group ($n = 14$) that were comparable in age, hearing level, and baseline proficiency. The control group followed the conventional programme; the experimental group was taught through the proposed technology.

The technology. The instructional technology integrated five interconnected components. (1) Visual-articulatory modelling provided slow-motion mouth-shape videos, visual-phonics hand cues, and speechreading practice so that articulatory targets were made visible. (2) Captioned multimedia input supplied short video and animated dialogues with synchronised subtitles, exploiting dual-channel (verbal plus pictorial) processing. (3) Real-time speech-visualisation and vibrotactile feedback used waveform and pitch-contour software, together with vibration cues, to give learners immediate visual and tactile information about loudness, rhythm, and intonation that they could not hear. (4) Scaffolded communicative tasks structured production through picture prompts, sentence frames, and role cards, moving learners from controlled to freer speech. (5) Total-communication mediation used fingerspelling and sign support as a bridge to spoken and written English, and organised paired and small-group interaction.

Instrument and assessment. Speaking performance was measured with an analytic rubric comprising four equally weighted criteria—intelligibility and pronunciation, lexical range, grammatical accuracy, and communicative effectiveness—each rated on a five-band scale and converted to a 0–100 composite score. Two trained raters scored video-recorded performances independently; inter-rater agreement was high. The same speaking task was administered at pre-test and post-test. *Data analysis.* Paired-samples t -tests examined within-group change, an independent-samples t -test compared the groups at post-test, and Cohen's d estimated the effect size.

3. RESULTS

Both groups began at a comparable baseline (experimental $M = 42.6$; control $M = 43.1$). After the intervention, the experimental group rose by 25.8 points, more than three times the gain recorded by the control group (8.1 points). Within-group improvement was statistically significant for both groups, but the magnitude differed markedly. The comparison of post-test scores yielded a significant between-group difference, $t(26) = 5.91$, $p < 0.001$, with a large effect size, Cohen's $d = 1.42$. Table 1 summarises the results.

Table 1. Pre- and post-test English speaking-skills scores (0–100) for the experimental and control groups

Group	n	Pre-test M (SD)	Post-test M (SD)	Mean gain	Paired t	p
Experimental	14	42.6 (6.8)	68.4 (7.9)	+25.8	12.41	< 0.001
Control	14	43.1 (7.1)	51.2 (7.5)	+8.1	4.07	< 0.01

Note. Between-group comparison at post-test: $t(26) = 5.91$, $p < 0.001$; Cohen's $d = 1.42$ (large effect).

Disaggregation by rubric criterion showed that the largest experimental-group gains occurred in intelligibility and communicative effectiveness, the two dimensions most directly targeted by the speech-visualisation and scaffolded-task components, while gains in grammatical accuracy were more modest in both groups.

4. DISCUSSION

The results indicate that a coordinated multimodal technology can produce substantial improvement in the English-speaking skills of students with hearing impairments, well beyond the progress achieved by conventional instruction. The pattern of gains is theoretically coherent. By converting the inaudible properties of speech—loudness, rhythm, and intonation—into visible and tactile information, the technology supplied the corrective feedback loop that hearing learners obtain auditorily; this is consistent with the principle that visual and multimodal access is decisive for language learning in deaf and hard-of-hearing students. The use of captioned, dual-channel input reflects the well-established benefit of presenting verbal and pictorial information together, while the scaffolded communicative tasks created the supported, socially mediated space in which higher functions develop.

Practically, the technology is feasible in resource-constrained inclusive settings, since several of its components rely on freely available speech-visualisation applications and short captioned materials rather than specialised laboratory equipment. The differentiated criterion-level results also carry a methodological implication: pronunciation and communicative effectiveness respond quickly to visual and tactile feedback, whereas grammatical accuracy appears to require longer, more explicit treatment, suggesting that future versions of the technology should strengthen the form-focused strand.

Several limitations should be acknowledged. The sample was small and drawn from a single regional context, the intervention lasted one semester, and the participants were learners with residual hearing rather than the profoundly deaf; the findings therefore generalise with caution. Future research

should involve larger and more diverse samples, longer interventions with delayed post-tests to assess retention, and comparison across different degrees of hearing loss.

5. CONCLUSION

This study designed and validated a multimodal pedagogical technology for developing the English speaking skills of students with hearing impairments. Integrating visual-articulatory modelling, captioned multimedia, real-time speech-visualisation and vibrotactile feedback, scaffolded communicative tasks, and total-communication mediation, the technology produced significantly greater oral gains than conventional instruction, with a large effect size. The findings support a shift from audio-centred to visually grounded, feedback-rich foreign-language methodology for this population, and offer a practicable model for inclusive English classrooms.

References

1. Marschark, M. (2007). *Raising and Educating a Deaf Child: A Comprehensive Guide to the Choices, Controversies, and Decisions Faced by Parents and Educators*. 2nd ed. New York; Oxford: Oxford University Press. (monograph)
2. Marschark, M., Lang, H. G., & Albertini, J. A. (2002). *Educating Deaf Students: From Research to Practice*. Oxford: Oxford University Press.
3. Mayer, R. E. (2009). *Multimedia Learning*. 2nd ed. Cambridge: Cambridge University Press.
4. Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, 108(6), 1017–1054.
5. Paul, P. V. (2009). *Language and Deafness*. 4th ed. Sudbury, MA: Jones & Bartlett Publishers.
6. Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Philological sciences

CAUGHT BETWEEN LANGUAGES: TRANSLANGUAGING, FEAR OF MISTAKES, SPEAKING CONFIDENCE

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Abstract

Speaking confidence is a critical component of successful language learning, particularly in multilingual educational contexts where learners are expected to communicate in a target language while simultaneously navigating multiple linguistic resources. Despite increased attention to communicative competence in language education, many learners continue to experience speaking anxiety and a persistent fear of making mistakes. These emotional barriers often limit classroom participation, reduce willingness to communicate, and negatively affect language development. At the same time, language policies in many educational settings continue to promote monolingual norms that discourage the use of learners' complete linguistic repertoires. Drawing upon translanguaging theory, foreign language anxiety research, and language policy scholarship, this conceptual article examines the relationship between translanguaging, fear of mistakes, speaking confidence, and institutional language ideologies. The article argues that restrictive language policies may unintentionally contribute to speaking anxiety by positioning errors as indicators of linguistic inadequacy and by limiting learners' access to familiar linguistic resources. In contrast, translanguaging creates opportunities for multilingual learners to utilize their complete linguistic repertoires, thereby reducing communicative pressure and promoting confidence. Building upon the work of García and Wei (2014), Horwitz et al. (1986), MacIntyre (1999), and Spolsky (2004), the article proposes that speaking confidence should be understood not solely as an individual psychological characteristic but as a socially and institutionally constructed phenomenon. The paper concludes that more flexible language policies and translanguaging-oriented pedagogies can contribute to emotionally supportive learning environments that encourage participation, reduce anxiety, and foster meaningful communication.

Keywords: translanguaging, speaking confidence, foreign language anxiety, fear of mistakes, language policy, multilingual education, learner emotions

Introduction

The ability to communicate effectively in more than one language has become increasingly important in contemporary societies characterized by globalization, mobility, and linguistic diversity. Educational institutions across the world place significant emphasis on developing learners' communicative competence, particularly in English, which continues to function as an international language in academic, professional, and intercultural contexts. As a result, speaking skills have become one of the primary objectives of language education.

Despite extensive instruction and growing opportunities for language learning, many students continue to experience considerable difficulties when communicating orally in a foreign language. One of the most frequently reported challenges is speaking anxiety. Learners often describe feelings of nervousness, embarrassment, self-consciousness, and fear when required to participate in oral communication activities. These emotional responses frequently reduce participation and limit opportunities for language development.

Research on foreign language anxiety has consistently identified speaking as the most anxiety-provoking language skill (Horwitz et al., 1986). Unlike reading or listening activities, speaking requires immediate language production in front of others. Learners must formulate ideas, select vocabulary, apply grammatical structures, and monitor pronunciation simultaneously while often being observed by teachers and peers. This combination of linguistic, cognitive, and social demands creates conditions in which anxiety can easily emerge.

Among the various factors contributing to speaking anxiety, fear of making mistakes occupies a particularly important position. Language learners frequently worry that grammatical inaccuracies, pronunciation errors, or vocabulary limitations will result in negative evaluation. Consequently, many learners avoid participation, remain silent during classroom discussions, or rely on memorized responses rather than engaging in spontaneous communication. Although mistakes constitute a natural and essential component of language learning, educational environments often unintentionally encourage learners to view them as indicators of failure.

Recent developments in multilingual education have challenged traditional assumptions regarding language learning and communication. In particular, translanguaging theory has transformed understandings of how multilingual individuals utilize language. García (2009) and García and Wei (2014) argue that multilingual speakers do not operate through separate and autonomous linguistic systems. Rather, they draw upon an integrated linguistic repertoire that allows them to communicate strategically across languages. This perspective challenges educational practices that require strict separation between languages and suggests alternative approaches to language teaching and learning.

Translanguaging has emerged as both a theoretical framework and a pedagogical approach that recognizes multilingual learners' complete linguistic repertoires as valuable educational resources. Rather than treating the use of multiple languages as evidence of linguistic deficiency, translanguaging views such practices as natural manifestations of multilingual communication. This perspective has significant implications for classroom participation, learner identity, and emotional well-being.

The relationship between translanguaging and learner emotions has become increasingly important within contemporary educational research. Emotions influence motivation, participation, persistence, and academic achievement. Learners who feel confident and supported are more likely to engage actively in communicative activities, whereas learners who experience anxiety often withdraw from opportunities for interaction. Consequently, understanding how classroom language practices affect emotional experiences is essential for effective language education.

Language policy represents another important factor influencing learner experiences. Educational institutions frequently establish policies regarding acceptable language use within classrooms. Many of these policies are grounded in monolingual ideologies that prioritize exclusive use of the target language. While such approaches are commonly justified as beneficial for language acquisition, scholars increasingly question their effectiveness and their impact on multilingual learners (García & Wei, 2014; Spolsky, 2004).

From a translanguaging perspective, restrictive language policies may inadvertently create communicative pressure by limiting learners' access to familiar linguistic resources. When students are prohibited from utilizing their complete linguistic repertoires, they may become more vulnerable to speaking anxiety and fear of mistakes. Thus, language policy becomes not merely a mechanism for regulating language use but also a factor shaping emotional experiences within educational environments.

This article examines the relationship between translanguaging, fear of making mistakes, language policy, and speaking confidence. Drawing upon translanguaging theory, foreign language anxiety research, and language policy scholarship, the paper argues that speaking confidence should be understood as a socially and institutionally constructed phenomenon rather than solely an individual characteristic. By exploring the emotional dimensions of multilingual education, the article contributes to ongoing discussions regarding inclusive and supportive approaches to language teaching.

Problem Statement

Despite growing recognition of multilingualism as a valuable educational resource, many language classrooms continue to operate within monolingual frameworks that prioritize exclusive target-language use. Such approaches remain particularly common in English as a Foreign Language (EFL) contexts, where students are often expected to communicate solely in English regardless of their linguistic backgrounds or proficiency levels. Although these policies are generally intended to maximize exposure to the target language, they may also produce unintended emotional consequences for learners.

One of the most significant consequences is speaking anxiety. Numerous studies have demonstrated that language learners frequently experience nervousness, fear, and self-consciousness when speaking a foreign language (Horwitz et al., 1986; MacIntyre, 1999). These emotional experiences often reduce participation and negatively influence language development. Among the factors contributing to anxiety, fear of making mistakes consistently emerges as one of the most influential.

The fear of making mistakes extends beyond concerns about language accuracy. Many learners perceive errors as indicators of incompetence or failure, particularly in educational environments where correctness is strongly emphasized. As a result, students may become reluctant to participate in

classroom discussions, ask questions, or engage in spontaneous communication. Such avoidance behaviors reduce opportunities for language practice and reinforce cycles of anxiety and silence.

At the same time, contemporary research in multilingual education challenges the assumption that language learning should occur through strict separation of languages. Translanguaging theory suggests that multilingual learners naturally utilize their complete linguistic repertoires when constructing meaning and communicating (García & Wei, 2014). Restricting access to these resources may increase cognitive and emotional pressure rather than facilitate learning.

Although translanguaging has received considerable scholarly attention, existing research has primarily focused on language development, literacy, and classroom interaction. Comparatively less attention has been devoted to understanding how translanguaging influences emotional dimensions of language learning, including speaking confidence and fear of mistakes.

Similarly, research on foreign language anxiety has largely concentrated on individual psychological characteristics while paying limited attention to institutional factors such as language policy and classroom language ideologies. Consequently, insufficient understanding exists regarding how language policies shape learners' emotional experiences and communicative behaviors.

This gap is particularly significant because language policies influence not only linguistic practices but also learners' perceptions of themselves as language users. Policies grounded in monolingual ideologies may unintentionally contribute to anxiety by emphasizing correctness, linguistic conformity, and target-language exclusivity. Conversely, translanguaging-oriented approaches may create more supportive environments that encourage participation and confidence.

Therefore, there is a need to examine the relationship between language policy, translanguaging practices, fear of making mistakes, and speaking confidence within multilingual educational contexts. Understanding these relationships can contribute to the development of more inclusive and emotionally supportive language learning environments.

Research Questions

This article addresses the following research questions:

1. How do language policies influence speaking confidence among multilingual EFL learners?
2. What role does fear of making mistakes play in the development of speaking anxiety?
3. How can translanguaging practices contribute to reducing anxiety and increasing speaking confidence?

Literature Review

Translanguaging as a Dynamic Theory of Multilingualism

Translanguaging has become one of the most influential concepts in multilingual education. While earlier approaches to bilingualism often conceptualized languages as separate and autonomous systems, translanguaging theory challenges this assumption by emphasizing the integrated nature of multilingual communication.

According to García (2009), multilingual individuals do not possess isolated language systems that function independently. Rather, they draw upon a unified linguistic repertoire that allows them to communicate strategically across different contexts. From this perspective, language practices cannot be fully understood through rigid distinctions between named languages. Instead, multilingual speakers utilize linguistic resources flexibly in response to communicative needs.

García and Wei (2014) further developed this perspective by defining translanguaging as the process through which multilingual individuals employ their complete linguistic repertoires to construct meaning, learn, and communicate. Translanguaging therefore reflects the natural communicative practices of multilingual speakers rather than deviations from linguistic norms.

This perspective represents a significant departure from traditional language teaching approaches. Conventional pedagogies often emphasize language separation and discourage movement between languages during instruction. Translanguaging theory, by contrast, recognizes multilingualism as a dynamic and fluid process. The use of multiple languages is viewed as a resource that supports learning rather than an obstacle that must be eliminated.

The educational implications of translanguaging are substantial. García and Wei (2014) argue that allowing learners to utilize their complete linguistic repertoires facilitates comprehension, promotes participation, and strengthens engagement with academic content. When students can draw upon familiar linguistic resources, they are better able to connect new knowledge with existing understandings.

Moreover, translanguaging contributes to identity affirmation. Educational systems frequently privilege certain languages while marginalizing others. Such practices may communicate that some aspects of learners' identities are more valuable than others. Translanguaging challenges this hierarchy by

validating the linguistic experiences of multilingual learners and recognizing their full linguistic repertoires as educational assets (García et al., 2017).

Consequently, translanguaging has evolved beyond a classroom strategy into a broader educational philosophy. It provides a framework for understanding multilingualism, learning, identity, and participation within increasingly diverse educational contexts.

Learner Emotions in Language Education

The role of emotions in language learning has received growing scholarly attention during the past several decades. Researchers increasingly recognize that language acquisition involves not only cognitive processes but also emotional experiences that shape learners' motivation, participation, and achievement. Emotions influence how learners perceive classroom experiences and how they respond to communicative challenges. Positive emotions such as confidence, enjoyment, and curiosity often encourage engagement and persistence. Negative emotions such as anxiety, fear, and embarrassment may inhibit participation and reduce willingness to communicate.

Within language education, speaking activities frequently generate strong emotional responses. Unlike receptive skills such as reading and listening, speaking requires learners to publicly demonstrate linguistic competence. Consequently, speaking situations often involve concerns regarding self-presentation and social evaluation.

García and Kley (2016) emphasize that multilingual learners' emotional experiences are closely connected to language practices and classroom environments. When learners are encouraged to utilize their linguistic resources, they often experience greater comfort and confidence. Conversely, environments that restrict language use may contribute to insecurity and exclusion.

This relationship highlights the importance of considering emotions within discussions of language pedagogy. Effective language learning environments must address not only linguistic development but also the emotional conditions that support participation and communication.

Foreign Language Anxiety and Fear of Making Mistakes

Foreign Language Anxiety (FLA) has long been recognized as one of the most influential affective variables in language learning. Horwitz et al. (1986) conceptualized FLA as a distinct form of anxiety associated specifically with language learning and communication. According to their framework, language anxiety consists of three major components: communication apprehension, test anxiety, and fear of negative evaluation. Among these dimensions, fear of negative evaluation is particularly relevant to speaking activities because learners often worry about how others will perceive their language performance.

Speaking anxiety emerges when learners perceive oral communication as threatening. Students may fear grammatical mistakes, pronunciation errors, limited vocabulary, or misunderstandings during interaction. Such concerns frequently result in avoidance behaviors, including silence, reduced participation, and reluctance to engage in classroom discussions.

MacIntyre (1999) argues that anxiety influences language learning by interfering with cognitive processing. Anxious learners devote substantial mental resources to monitoring performance and anticipating mistakes. Consequently, fewer cognitive resources remain available for communication itself. The fear of making mistakes plays a particularly important role within this process. Many learners associate mistakes with failure or incompetence rather than viewing them as natural components of language development. This perception often leads to perfectionistic tendencies that discourage risk-taking and spontaneous communication.

Importantly, fear of making mistakes is not solely an individual characteristic. Classroom environments and educational expectations influence how learners interpret errors. When mistakes are treated as evidence of inadequacy, anxiety increases. When mistakes are framed as opportunities for learning, learners may feel more comfortable participating in communicative activities.

Language Policy and Monolingual Ideologies

Language policy plays a central role in shaping educational experiences, classroom interactions, and opportunities for language learning. Traditionally, language policy has been understood as a set of official decisions and regulations concerning language use within institutions and societies. However, contemporary scholars argue that language policy extends beyond formal regulations and includes broader beliefs, ideologies, and assumptions about language and communication (Spolsky, 2004).

According to Spolsky (2004), language policy consists of three interconnected dimensions: language practices, language beliefs, and language management. Language practices refer to the actual ways languages are used in everyday communication. Language beliefs encompass societal attitudes and

ideologies regarding language use, while language management involves deliberate attempts to regulate language behavior through official policies and institutional decisions.

Within educational settings, language policies often reflect monolingual ideologies. Monolingual ideologies assume that languages should remain separate and that effective language learning occurs through exclusive use of the target language. These assumptions continue to influence language education in many countries, particularly within English language teaching programs.

Target-language-only policies are frequently justified through the belief that maximum exposure leads to maximum learning. According to this perspective, allowing students to use their first language may reduce opportunities to practice the target language and therefore hinder language development. As a result, many educational institutions encourage or require students to communicate exclusively in English during lessons.

However, scholars increasingly question the effectiveness of such approaches. García and Wei (2014) argue that monolingual policies fail to recognize the realities of multilingual communication. Multilingual individuals naturally draw upon multiple linguistic resources when constructing meaning. Consequently, policies that prohibit learners from using their existing linguistic knowledge may create unnecessary barriers to communication and learning.

Furthermore, monolingual policies may influence learners' emotional experiences. When students are expected to communicate exclusively in a language they have not yet fully mastered, they often experience increased pressure and self-consciousness. Communication becomes associated with surveillance and evaluation rather than exploration and learning.

From this perspective, language policies contribute to the creation of classroom norms regarding what constitutes legitimate language use. Learners quickly become aware of which linguistic practices are valued and which are discouraged. These messages influence not only language behavior but also perceptions of competence, belonging, and identity.

García et al. (2017) argue that educational systems frequently privilege monolingual norms despite serving increasingly multilingual populations. Such practices may unintentionally marginalize multilingual learners by treating their existing linguistic resources as problems rather than strengths. Consequently, language policy becomes closely connected to issues of participation, inclusion, and learner confidence.

The relationship between language policy and speaking confidence is particularly significant. Policies emphasizing linguistic correctness and target-language exclusivity may encourage learners to focus excessively on avoiding mistakes. Instead of viewing communication as an opportunity to express ideas, students may perceive speaking situations as tests of linguistic accuracy. Such perceptions contribute to anxiety and reduced willingness to communicate.

Therefore, language policy should not be viewed solely as an administrative framework. It also functions as a powerful social and emotional force that shapes how learners experience language learning. Understanding speaking confidence requires attention to these broader institutional influences.

Translanguaging and Emotional Safety

One of the most significant contributions of translanguaging theory is its potential to create emotionally supportive learning environments. Although translanguaging is often discussed in relation to language development and academic achievement, its emotional dimensions are equally important.

Emotional safety refers to learners' perceptions that they can participate, take risks, and make mistakes without fear of humiliation or negative judgment. Such environments are particularly important in language classrooms because communication inherently involves uncertainty and experimentation.

García and Wei (2014) argue that translanguaging promotes participation by allowing learners to utilize all available linguistic resources during communication. Rather than requiring immediate linguistic perfection, translanguaging enables learners to focus on meaning-making and interaction. This shift reduces communicative pressure and encourages engagement.

The relationship between translanguaging and emotional safety can be understood through several mechanisms. First, translanguaging reduces cognitive overload. Learners are not required to suppress their existing linguistic knowledge while simultaneously producing language in a less familiar system. Access to multiple linguistic resources facilitates communication and reduces frustration.

Second, translanguaging decreases fear of making mistakes. In monolingual environments, errors often become highly visible because learners are evaluated according to narrow standards of linguistic accuracy. Translanguaging shifts attention away from perfection and toward successful communication. As a result, mistakes are more likely to be interpreted as normal aspects of learning rather than evidence of failure.

Third, translanguaging supports identity affirmation. García (2009) emphasizes that multilingual learners possess complex linguistic identities that cannot be adequately represented through monolingual frameworks. Educational environments that recognize and value these identities contribute to stronger feelings of belonging and self-worth.

The importance of belonging should not be underestimated. Learners who feel accepted and valued within educational communities are more likely to participate actively in classroom activities. Conversely, learners who perceive aspects of their identities as unwelcome may withdraw from interaction.

Translanguaging therefore functions as more than a communication strategy. It creates opportunities for learners to bring their complete selves into the classroom. By validating linguistic diversity, translanguaging contributes to environments characterized by trust, inclusion, and confidence. These emotional benefits have important implications for speaking development. Students who feel emotionally secure are more willing to experiment with language, ask questions, and participate in discussions. Increased participation creates additional opportunities for practice and feedback, which ultimately support language development. Thus, translanguaging can be understood as a mechanism that simultaneously promotes communication, emotional well-being, and language learning. Rather than viewing multilingualism as a challenge to overcome, translanguaging positions linguistic diversity as a resource that strengthens educational experiences.

Research Gap

Despite substantial scholarly interest in multilingual education, significant gaps remain in the existing literature.

First, much translanguaging research focuses primarily on linguistic and academic outcomes. Studies frequently examine comprehension, literacy development, classroom participation, and language achievement. While these contributions are valuable, comparatively limited attention has been devoted to emotional variables such as speaking confidence, fear of making mistakes, and communication-related anxiety.

Second, research on foreign language anxiety often concentrates on individual learner characteristics. Anxiety is frequently discussed in relation to personality traits, self-esteem, motivation, or language proficiency. Although these factors are important, such approaches may overlook broader institutional influences. Relatively little research examines how language policies and educational ideologies contribute to anxiety and confidence.

Third, language policy scholarship traditionally focuses on language planning, language rights, and educational outcomes. Emotional dimensions of language policy remain comparatively underexplored. Consequently, insufficient understanding exists regarding how policy decisions shape learners' emotional experiences and willingness to communicate.

Fourth, existing studies tend to investigate translanguaging, language policy, and language anxiety as separate phenomena. However, these concepts are deeply interconnected within multilingual educational contexts. Learners' emotional experiences are influenced simultaneously by classroom practices, institutional expectations, and opportunities to utilize their linguistic repertoires.

Finally, while García's translanguaging framework has transformed contemporary understandings of multilingualism, more conceptual work is needed to explain how translanguaging mediates the relationship between language policy and speaking confidence. Understanding this relationship is particularly important in EFL contexts where monolingual ideologies continue to dominate classroom practice.

Addressing these gaps can contribute to a more comprehensive understanding of language learning experiences. By integrating translanguaging theory, language policy scholarship, and foreign language anxiety research, the present article seeks to provide a holistic perspective on speaking confidence in multilingual educational settings.

Theoretical Framework

This article is guided by three complementary theoretical perspectives: Translanguaging Theory, Foreign Language Anxiety Theory, and Language Policy Theory. Together, these frameworks provide a comprehensive lens through which the relationship between language practices, learner emotions, and speaking confidence can be understood.

Translanguaging Theory

The primary theoretical foundation of this article is translanguaging theory, developed extensively by García (2009) and García and Wei (2014). Translanguaging theory challenges traditional views of multilingualism that conceptualize languages as separate and autonomous systems. Instead, it proposes that multilingual individuals draw upon a unified linguistic repertoire when communicating and making meaning. From this perspective, language boundaries are socially constructed rather than

psychologically fixed. Multilingual speakers utilize linguistic features flexibly according to communicative needs. Consequently, educational practices that require strict language separation may not accurately reflect how multilingual individuals naturally communicate and learn. For the purposes of this article, translanguaging theory provides a framework for understanding how access to multiple linguistic resources may influence speaking confidence and emotional well-being.

Foreign Language Anxiety Theory

Foreign Language Anxiety Theory, originally proposed by Horwitz et al. (1986), conceptualizes language anxiety as a distinct situation-specific psychological construct that emerges in the context of second and foreign language learning. Unlike general anxiety, foreign language anxiety is directly related to the processes of language production, comprehension, and evaluation.

Horwitz et al. (1986) identify three core components of foreign language anxiety: communication apprehension, test anxiety, and fear of negative evaluation. Communication apprehension refers to the fear or discomfort associated with real or anticipated communication in the target language. Test anxiety is related to performance situations in which learners are evaluated, while fear of negative evaluation reflects concerns about being judged by teachers or peers.

Among these dimensions, fear of negative evaluation is particularly relevant to speaking confidence. Oral communication is inherently public and immediate, which increases learners' exposure to potential criticism. As a result, learners may become overly concerned with how others perceive their linguistic performance.

MacIntyre (1999) further expands this framework by emphasizing the dynamic relationship between anxiety and language performance. He argues that anxiety not only affects communication behavior but also interferes with cognitive processing during language use. Anxious learners may struggle to retrieve vocabulary, construct sentences, or process input efficiently due to the division of attention between meaning-making and self-monitoring.

This cognitive disruption contributes to reduced fluency and increased hesitation during speaking tasks. Consequently, learners may perform below their actual linguistic competence, reinforcing negative self-perceptions and further increasing anxiety.

Within this framework, fear of making mistakes plays a central role. Mistakes are often interpreted by learners as evidence of linguistic failure or inadequacy, particularly in environments where accuracy is emphasized over communication. This interpretation can lead to avoidance behaviors, including silence, reduced participation, or reliance on memorized expressions.

Importantly, foreign language anxiety is not solely an internal psychological condition. It is shaped by contextual and environmental factors, including classroom atmosphere, teacher expectations, and institutional language policies. Therefore, addressing speaking anxiety requires attention to both individual and systemic dimensions of language learning.

Language Policy Theory

Language Policy Theory provides a macro-level perspective on how institutional and ideological structures influence language use and learner experiences. According to Spolsky (2004), language policy consists of three interrelated components: language practices, language beliefs, and language management.

Language practices refer to the actual linguistic behaviors observed in specific contexts. Language beliefs encompass ideological views about language, including assumptions about language superiority, correctness, and appropriateness. Language management refers to deliberate efforts by institutions or authorities to regulate language use through rules, curricula, or pedagogical guidelines.

In many educational systems, language policy is shaped by monolingual ideologies that prioritize the use of a single target language within instructional settings. These ideologies often manifest in English-only policies, where learners are expected to avoid using their first language during classroom activities.

While such policies are often justified on pedagogical grounds, they may produce unintended consequences. García and Wei (2014) argue that monolingual policies fail to reflect the linguistic realities of multilingual learners. In practice, learners naturally draw upon multiple linguistic resources to construct meaning, even when instructed otherwise.

Restrictive language policies may also influence learners' emotional experiences. When students are required to use only the target language, they may feel increased pressure to produce error-free speech. This pressure can intensify fear of making mistakes and reduce willingness to participate in communicative activities.

Furthermore, language policy communicates implicit messages about linguistic legitimacy and identity. When learners' home languages are excluded from the classroom, they may interpret this exclusion as a devaluation of their linguistic identities. Such perceptions can negatively affect self-confidence and sense of belonging.

García et al. (2017) emphasize that educational systems often privilege monolingual norms despite serving linguistically diverse populations. This mismatch between policy and linguistic reality creates tensions that directly affect learner participation and emotional engagement. Thus, language policy should be understood not only as a regulatory framework but also as an ideological and emotional force that shapes learners' experiences of language learning.

Integrated Conceptual Framework

Building on the three theoretical perspectives discussed above, this article proposes an integrated conceptual framework that explains the relationship between language policy, translanguaging, fear of making mistakes, and speaking confidence. At the macro level, language policy establishes the ideological and institutional conditions under which language learning takes place. Monolingual policies prioritize target-language exclusivity and emphasize linguistic accuracy. These policies influence classroom norms and shape learners' expectations regarding acceptable language use.

At the meso level, classroom practices reflect and operationalize these policies. In monolingual environments, learners are often discouraged from using their first language, which increases cognitive and communicative demands. This restriction may heighten awareness of potential errors and intensify self-monitoring during speaking tasks.

At the micro level, learners experience emotional responses to these conditions. Fear of making mistakes emerges as a central emotional reaction to perceived linguistic risk. This fear contributes to communication apprehension, reduced participation, and avoidance behaviors.

Translanguaging functions as a mediating and moderating mechanism within this system. When translanguaging practices are permitted, learners are able to draw upon their full linguistic repertoires, reducing cognitive load and communicative pressure. This flexibility promotes emotional safety, decreases anxiety, and enhances speaking confidence. In this framework, speaking confidence is not viewed as a fixed individual trait but as a dynamic outcome emerging from interactions between institutional policies, classroom practices, and learner emotions. Confidence develops when learners experience supportive environments that allow linguistic flexibility and reduce fear of negative evaluation.

Discussion

The analysis presented in this article highlights several key insights regarding the relationship between translanguaging, language policy, fear of making mistakes, and speaking confidence.

First, monolingual language policies, although often implemented with the intention of improving language proficiency, may unintentionally contribute to increased speaking anxiety. By emphasizing exclusive target-language use and linguistic accuracy, such policies can create environments in which mistakes are highly salient and potentially stigmatized. As a result, learners may become more focused on error avoidance than on meaningful communication.

Second, fear of making mistakes emerges as a central mechanism linking language policy and speaking confidence. When learners perceive mistakes as indicators of failure rather than natural components of language learning, they are more likely to experience communication apprehension. This fear can significantly reduce participation and limit opportunities for language development.

Third, translanguaging offers an alternative approach that reconfigures the relationship between language, learning, and emotion. By allowing learners to utilize their full linguistic repertoires, translanguaging reduces communicative pressure and creates more inclusive learning environments. This shift enables learners to focus on meaning-making rather than linguistic perfection.

Fourth, speaking confidence should be understood as a socially and institutionally constructed phenomenon rather than an individual psychological attribute. Confidence develops within specific educational contexts that either support or restrict linguistic expression. Therefore, improving speaking confidence requires attention not only to learner psychology but also to classroom practices and institutional policies.

Pedagogical Implications

The findings of this conceptual analysis have several important implications for language teaching practice, curriculum design, and language policy development. These implications are particularly relevant in multilingual EFL contexts where learners are expected to develop communicative competence in a target language while navigating diverse linguistic repertoires.

First, language teachers should reconsider the strict enforcement of monolingual classroom practices. While target-language exposure remains important for language development, exclusive English-only policies may unintentionally increase anxiety and reduce speaking confidence. Instead, teachers can adopt flexible pedagogical approaches that allow strategic use of learners' first languages to support comprehension, idea generation, and participation.

Second, translanguaging should be recognized as a legitimate pedagogical resource rather than a deficiency or interference. As García and Wei (2014) argue, multilingual learners naturally draw upon their full linguistic repertoires when meaning-making. Allowing students to engage in translanguaging practices can reduce cognitive load, support deeper understanding, and encourage more active participation in speaking tasks.

Third, teachers should actively work to reduce fear of making mistakes in classroom environments. This can be achieved by reframing errors as natural and productive elements of language learning rather than indicators of failure. When mistakes are normalized as part of the learning process, learners are more likely to take communicative risks and engage in spontaneous speech.

Fourth, classroom assessment practices should be aligned with communicative and confidence-building goals. Overemphasis on grammatical accuracy during speaking activities may reinforce anxiety and discourage participation. Alternative assessment approaches that value fluency, meaning-making, and interactional effectiveness may contribute to more supportive learning environments.

Fifth, teacher education programs should include training on multilingual pedagogies and translanguaging theory. Many educators continue to operate within monolingual paradigms due to lack of exposure to alternative frameworks. Professional development in translanguaging can help teachers better understand multilingual learners' needs and design more inclusive instructional practices.

Finally, policymakers should reconsider rigid language policies that enforce strict separation of languages in educational settings. More flexible language policies that acknowledge linguistic diversity can contribute to improved emotional well-being, increased participation, and enhanced speaking confidence among learners.

Conclusion

This article examined the complex relationship between translanguaging, fear of making mistakes, language policy, and speaking confidence in multilingual educational contexts. Drawing upon translanguaging theory (García, 2009; García & Wei, 2014), foreign language anxiety research (Horwitz et al., 1986; MacIntyre, 1999), and language policy theory (Spolsky, 2004), the study argued that speaking confidence is not merely an individual psychological characteristic but a socially and institutionally constructed phenomenon.

The analysis demonstrated that monolingual language policies may unintentionally contribute to speaking anxiety by emphasizing linguistic correctness and restricting access to learners' full linguistic repertoires. Within such environments, fear of making mistakes becomes a central emotional barrier that limits participation and reduces opportunities for meaningful communication.

In contrast, translanguaging was identified as a powerful pedagogical and theoretical framework that can support emotional safety and enhance speaking confidence. By allowing learners to draw upon their complete linguistic resources, translanguaging reduces communicative pressure, encourages participation, and validates multilingual identities.

The article further highlighted that speaking confidence emerges through the interaction of institutional policies, classroom practices, and learner emotions. As such, improving confidence in language learning requires systemic changes that go beyond individual effort and address broader educational ideologies. Future research should further investigate the emotional dimensions of translanguaging and explore how different language policy environments shape learner confidence across diverse sociolinguistic contexts. In particular, empirical studies are needed to complement conceptual work and provide classroom-based evidence of how translanguaging practices influence speaking anxiety and learner emotions. Ultimately, this article argues that multilingual education should move away from deficit-oriented, monolingual frameworks and toward more inclusive approaches that recognize the value of linguistic diversity. Such a shift has the potential to transform language classrooms from spaces of anxiety and surveillance into spaces of participation, confidence, and meaningful communication.

References

1. Baker, C. (2011). *Foundations of bilingual education and bilingualism* (5th ed.). Multilingual Matters.

2. Canagarajah, S. (2011). *Translanguaging in the classroom: Emerging issues for research and pedagogy*. *Applied Linguistics Review*, 2(1), 1–28.
3. García, O. (2009). *Bilingual education in the 21st century: A global perspective*. Wiley-Blackwell.
4. García, O., & Kleyn, T. (Eds.). (2016). *Translanguaging with multilingual students: Learning from classroom moments*. Routledge.
5. García, O., Johnson, S. I., & Seltzer, K. (2017). *The translanguaging classroom: Leveraging student bilingualism for learning*. Caslon.
6. García, O., & Wei, L. (2014). *Translanguaging: Language, bilingualism and education*. Palgrave Macmillan.
7. Horwitz, E. K., Horwitz, M. B., & Cope, J. (1986). Foreign language classroom anxiety. *The Modern Language Journal*, 70(2), 125–132.
8. MacIntyre, P. D. (1999). Language anxiety: A review of the research for language teachers. In D. J. Young (Ed.), *Affect in foreign language and second language learning* (pp. 24–45). McGraw-Hill.
9. Spolsky, B. (2004). *Language policy*. Cambridge University Press.

DOMINANT FEATURES AND FUNCTIONS OF POLITICAL DISCOURSE

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ДОМИНАНТНЫЕ ПРИЗНАКИ И ФУНКЦИИ ПОЛИТИЧЕСКОГО ДИСКУРСА

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Abstract

The article examines the dominant features and main functions of political discourse as a special form of institutional communication. The formation of political linguistics is traced, the main approaches to the definition of political communication presented in the domestic and foreign scientific tradition are analyzed. Special attention is paid to the role of political communication in shaping public opinion, implementing power relations and influencing mass consciousness. The levels of political communication, types of political messages, as well as the genre-discursive classification of political communication products proposed by A.P. Chudinov are described. It is emphasized that modern political texts are characterized by polyfunctionality, a combination of various genre features, communicative strategies and manipulative mechanisms. The results obtained serve as a theoretical basis for further research of military-political discourse and its specific communicative characteristics.

Аннотация

В статье рассматриваются доминантные признаки и основные функции политического дискурса как особой формы институциональной коммуникации. Прослеживается становление политической лингвистики, анализируются основные подходы к определению политической коммуникации, представленные в отечественной и зарубежной научной традиции. Особое внимание уделяется роли политической коммуникации в формировании общественного мнения, реализации властных отношений и воздействию на массовое сознание. Описываются уровни политической коммуникации, типы политических сообщений, а также жанрово-дискурсивная классификация продуктов политической коммуникации, предложенная А.П. Чудиновым. Подчеркивается, что современные политические тексты характеризуются полифункциональностью, сочетанием различных жанровых признаков, коммуникативных стратегий и манипулятивных механизмов. Полученные результаты служат теоретической основой для дальнейшего исследования военно-политического дискурса и его специфических коммуникативных характеристик.

Keywords: political discourse, political communication, political linguistics, institutional discourse, political text, genres of political discourse, communicative strategies, political influence, public opinion, manipulation of consciousness, military-political discourse.

Ключевые слова: политический дискурс, политическая коммуникация, политическая лингвистика, институциональный дискурс, политический текст, жанры политического дискурса, коммуникативные стратегии, политическое воздействие, общественное мнение, манипуляция сознанием, военно-политический дискурс.

Введение

В любой сфере человеческой деятельности, в том числе и в политике, главенствующую роль, несомненно, играет коммуникация. Оговорим, что терминологическая единица «коммуникация» в современном понимании была прочно закреплена в вокабуляре политической науки относительно недавно.

Впервые данная терминологическая единица в контексте политики встречается в начале прошлого столетия: коммуникация трактовалась как передача определенной политической информации. Более того, считалось, что информация политического характера самая важная из всех существующих коммуникационных услуг [Цыганков 1999: 57]. С этим можно согласиться, ибо именно коммуникация является центральным элементом взаимодействия политических партий, политических деятелей, стран. Она обеспечивает адекватную передачу чувств, различных эмоций (позитивных и негативных), знаний, мыслей, информации т.д.

Отметим, что непосредственной точкой отсчёта появления политической лингвистики как особого раздела языкознания стали 20-е годы прошлого столетия. Толчком послужила Первая мировая война, в процессе которой было выявлено, что параллельно с огнестрельным оружием внушительный поражающий эффект может иметь и соответствующая словарная единица, словосочетание, предложение, вложенные в уста умелого и влиятельного профессионального пропагандиста.

Далее исследователи разных областей знания стали рассматривать определенные механизмы формирования общественного мнения с помощью именно политической коммуникации. В этом контексте мы можем упомянуть интересные работы Гарольда Лассуэлла [Lasswell 1946, 1948, 1966], Пола Лазарсфельда [Lazarsfeld, Merton 1948, Lazarsfeld, Berelson, Gaudet, 1948], Уолтера Липпманна [Lippmann 1915, 1916, 1917, 1922, 1958, 1965].

60-80 годы прошлого столетия – это следующий этап развития политической лингвистики: фокус научного исследования смещается – с тоталитарного и доминирующего дискурса в демократических государствах на профессиональную риторику. Здесь следует особо выделить работы Франкфуртской школы и французской школы анализа дискурса в лице Джона Дюбуа [Du Bois 1993], Жан Жака Куртина [Courtine 1988], Мишеля Фуко [Фуко 1994, 1996, 2004]. Представители данного направления стали исследовать наряду с содержанием текста интенции автора, сравнивая/сопоставляя содержание рассматриваемого материала с интрадискурсом и интердискурсом.

В 1947 году немецкий филолог Виктор Клемперер издает работы «LTI. Язык Третьего рейха. Записная книжка филолога» [Клемперер 1998 – переиздание]. Автор тщательно анализирует влияние языка на массовое сознание. В 1982 году Дж. Оруэлл пишет роман-антиутопию «1984», где пытается показать, как «newspeak» меняет сознание его носителя.

Характеристики политического дискурса

Среди основных характеристик политического дискурса А.П. Чудинов и Э.В. Будаев отмечают заметную «глобализацию» политической коммуникации.

Определения понятия политической коммуникации неоднозначны. Приведем некоторые из них.

⇒ Политическая коммуникация — это процесс передачи политической информации. В результате она начинает циркулировать от одного фрагмента политической системы к другой, а также функционировать между социальной и политической системой [Кретов, 2000, с. 101].

⇒ Политическая коммуникация – это конкретная речевая деятельность, которая ориентирована на пропаганду определенных политических идей. В результате она имеет ярко выраженное эмоциональное воздействие на население, тем самым подталкивая его к желаемым политическим действиям. Политическая коммуникация нужна также для выработки общественного согласия и обоснования социально-политических решений в атмосфере различных точек зрения общества [Чудинов 2006, с. 6].

⇒ А. Н. Баранов и Е. Г. Казакевич рассматривают политический дискурс в ракурсе образования определенной совокупности всех речевых актов, которые используются в политических коммуникативных процессах. Авторы также подчеркивают его институциональность [Баранов 2001: 6].

⇒ Близкая точка зрения: политический дискурс рассматривается как институциональное общение. Однако это общение, в отличие от лично ориентированного, использует свою конкретную систему знаков с профессиональной направленностью, т.е. имеет собственный подязык, а именно: специфическую лексику, фразеологию и паремиологию [Лассвелл 2006: 264].

⇒ Немецкие исследователи Отфрид, Яррена, Патрик, Донгес и др. говорят о том, что трудности в трактовке терминологического сочетания «политическая коммуникация» связаны непосредственно с тем, что его базисные составляющие, коими являются, соответственно, «коммуникация» и «политика» – это объекты исследований многих отраслей науки, которые применяют для своих исследований разные, иногда диаметрально противоположные теоретические подходы.

⇒ По некоторым источникам, политическая коммуникация – это коммуникация, которая посвящена непосредственно проблемам политического контекста. Ее можно охарактеризовать и как коммуникацию, авторами текстов которой являются политические субъекты.

⇒ Американский политолог Л. Пай в политическую коммуникацию включает практически все формы коммуникационных и неформальных контактов, осуществляемых в обществе, которые оказывают разнообразное воздействие на политику» [Рые 1987: 442].

Таким образом, политическую коммуникацию можно трактовать как передачу и обмен различными политическими идеями, информацией в политической сфере между политическими субъектами и гражданами, пользуясь при этом различными символами. Политическую коммуникацию можно также считать своего рода механизмом, в результате работы которого имеет место реализация власти в данном обществе.

Политическая коммуникация просматривается на двух конкретных уровнях:

⇒ **Формальном:** с помощью средств массовой коммуникации пропагандируются национальные ценности и нормы данного общества, в результате чего происходит формирование общественного мнения.

⇒ **Неформальном:** используются всевозможные личные связи и контакты через так называемых «лидеров мнений/opinion leaders».

В контексте вышесказанного информационные потоки можно разделить на следующие уровни:

1. Уровень циркуляции информации служебного характера (он обслуживает органы власти, управления).

2. Уровень образования информационной среды вокруг политических группировок и партий: это всевозможные политические программы, уставы партий, уставные документы, а также определенная информация, связанная с деятельностью политиков.

3. Уровень обращения к общественному мнению, к массовому сознанию, к политическому поведению.

Причем каждой государственной политической системе свойственны специфические особенности коммуникации, которые должны обеспечить эффективность политической системы, а также ее способность адекватного реагирования на внешние воздействия.

В процессе политической коммуникации адресату передаются такие типы политических сообщений, как:

⇒ **информативные** - сведения реальные, либо вымышленные;

⇒ **фактические** - информация, связанная с установлением/поддерживанием контактов между субъектами политики, а также различных политических связей;

⇒ **побудительные** - убеждение или приказ.

Целенаправленность политико-коммуникативных процессов на поддержание диалога и взаимопонимание в политической и социальной сферах является отражением стабильности данной политической системы.

Политические сообщения остаются главным аспектом политики, т.к. всю политически значимую информацию мы получаем непосредственно благодаря распространяемым по разным каналам массовой коммуникации сообщениям. Именно благодаря данным сообщениям становится возможным с определенной долей точности прогнозирование будущих событий или же ретроспективное обращение к политически важным событиям, происходившим в прошлом.

Интересно замечание Кеннета Бёрка о том, что львиная доля нашей реальности формируется вербальным способом. А весьма незначительная доля реальности познается на основе собственного опыта. В то же время окончательная картина создается на основе системы символов [Burke 1945, Burke 1966].

Если рассмотреть абстрактные понятия, такие, как, например, «справедливость», «демократия» и ряд политических феноменов, то можно обнаружить, что эмпирической основы не существует. А их толкование зависит от вполне конкретных вербальных символов. Идентичное можно утверждать о подавляющем большинстве политических явлений. [DeVito 2005, p.5].

Общеизвестно, что над политическим текстом трудится группа соответствующих квалифицированных специалистов, при этом именно политический лидер несёт огромную ответственность за контент данного текста. Таким образом, перед тем, как политический текст подписывать, отправлять в печать или озвучивать, следует детально проверить его, тщательно ознакомиться с каждым пунктом, поскольку возможная критика положений, указанных в документе, будет звучать в адрес именно конкретного политика, а не его политической группы.

Возникают правомерные вопросы: каким образом создаются политические тексты-послания народу? Какие скрытые невербальные мотивы они в себе несут и как правильно их трактовать?

Для ответа необходимо осознать, на кого именно ориентирован конкретный текст-послание, а также каковы его главная цель и задачи, а также предполагаемые результаты. Весьма

подробно эта проблема была рассмотрена А.П. Чудиновым, который в своей статье «Дискурсивные характеристики политической коммуникации» предложил собственную классификацию продуктов политической коммуникации [Чудинов 2012]. Классификация автора интересна. Считаем, что она может стать адекватной базой как для создания, так и для правильной интерпретации политических текстов.

Жанрово-дискурсивная дифференциация продуктов политической коммуникации

Продукты политической коммуникации можно классифицировать следующим образом:

1. Продукты, связанные с субъектом, т.е. автором или говорящим - выделяют такие виды политической коммуникации, как:

- собственно политическая коммуникация;
- медийная политическая коммуникация;
- непрофессиональная политическая коммуникация, где в роли автора может выступать избиратель, представитель народа и т.д.

2. Продукты, связанные с адресатом - различают такие виды политической коммуникации, как:

- адресат — политик или политический субъект, т.е. государство, партии и др.;
- адресат не относится к числу институциональных политических субъектов (читатель, зритель, «избиратель», наблюдатель).

3. Сопоставление устной или письменной речи ведется особым способом, а именно - по жанрам: жанры устной речи (выступление на многочисленных митингах, собраниях, дискуссии, дебаты в политических кругах, круглые столы, выступление на саммитах, конференциях, собраниях, митингах, в парламенте, интервью, доклады, беседы и т.д.); жанры письменной речи (газетные статьи, статьи в политических журналах, статьи, размещенные на сайтах, программы (в том числе и предвыборные), партийные листовки (в том числе и электронные, прокламации, письма политическим лидерам и т.д.).

4. При анализе монологической и диалогической речи разграничение жанров на такие, как: монологические жанры (выступление по телевидению, радиообращения, статьи в журналах, газетах и т.д.); диалогические жанры (дискуссии, диспуты, политические диалоги, переговоры, саммиты и т.д.).

5. По функциям различают: ритуальные жанры (инаугурационные обращения, официальные сообщения, приветственные слова и т.д.); ориентационные жанры (доклады, указы, договоры, соглашения); агональные жанры, содержащие призывы к борьбе (лозунги, листовки, выступления на собраниях, митингах, речевки); информативные жанры (газетная информация, информация, размещенная в Интернете, обращения граждан к политикам или в СМИ).

6. По объёму информации среди жанров различают: малые жанры (лозунг, слоган, речевка); средние жанры (выступление на митинге или в парламенте (национальном собрании и пр.), листовка, газетная статья и др.); крупные жанры (партийная программа, политический доклад, предвыборная речь политического лидера, книга политической публицистики и др.).

7. По цели высказывания различают информативные, оценочные и императивные (призывающие к действию) жанры [Чудинов 2006].

Заключение

Важно знать, что все названные жанровые признаки могут встречаться в одном и том же тексте одновременно. В настоящее время (первая половина XXI века) это становится нормой. Например, предвыборные агитационные листовки, содержащие положительную личную информацию о кандидате, о его больших несомненных заслугах и неопровержимых достоинствах в большинстве случаев оказывают серьезное манипулятивное влияние, как некий призыв оказать ему однозначное доверие.

В литературе встречаются политические тексты, в которых заметно преобладает только один из указанных жанровых признаков. Например, в автобиографических книгах политических лидеров, воспоминаниях государственных деятелей и т.д. преимущественно преобладает именно информативный жанр.

Центральная роль обычно отдаётся авторству текста и его конкретной адресности, месту, времени и целям его создания, стратегиям и тактикам автора.

Существует много различий дискурсивных характеристик политических текстов и тех же характеристик только уже иных текстов - художественных, педагогических, научных и т.д. Для понимания этих различий следует рассмотреть конкретно военно-политический дискурс и проанализировать ведущие дискурсивные характеристики военной коммуникации.

References

1. Tsygankov P. A. *International processes in the context of globalization: the problem of effective communication* / P. A. Tsygankov. — Text : direct // *Bulletin of the Moscow University. Series 18, Sociology and Political Science*. 1999. No. 4. pp. 56-65. [Опубликовано на русском языке]
2. Chudinov A.P. *Political linguistics*. Moscow: Flint, Nauka, 2006 - 255 p. [Опубликовано на русском языке]
3. Chudinov A.P. *Discursive characteristics of political communication* / *Political linguistics*. 2012, No. 2. pp. 53-59. [Опубликовано на русском языке]
4. Burke, K. *A Grammar of Motives* / K. Burke. — New York: Prentice-Hall, 1945. — 533 p.
5. Burke, K. *Terministic Screens* // Burke, K. *Language as Symbolic Action: Essays on Life, Literature, and Method*. — Berkeley: University of California Press, 1966. — P. 44–62.
6. Pye L. *Political Communication* / L. Pye // *The Blackwell Encyclopedia of Political Institutions* / ed. by V. Bogdanor. Oxford; New York: Blackwell Reference, 1987. P. 442.
7. Baranov A. N., Kazakevich E. G. *Parliamentary debates: Traditions and innovations (Soviet political language: from ritual to metaphor)*. Moscow: Znanie, 1991. 64 p. [Опубликовано на русском языке]
8. Lasswell G. *The language of power* / *Political linguistics*. — Issue 20. — Yekaterinburg, 2006. — pp. 264-279. [Опубликовано на русском языке]
9. Klemperer V. LTI. *The language of the Third Reich. Philologist's Notebook* / V. Klemperer; translated from German by A. B. Grigoriev. Moscow: Progress-Tradition, 1998. 384 p. [Опубликовано на русском языке]

Physical sciences

PLANET EARTH IS STRUCTURED BY NATURE DIFFERENTLY THAN IT IS STATED BY MODERN SCIENCE¹

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Abstract

Time travels on Earth is now physically possible and technically feasible. Moreover, time travels is already being performed daily by millions of airplane passengers. But since such time travels of air passengers is combined with mandatory travels over long distances, they are not currently used. Therefore, in order to make time travels suitable for practical use, it is proposed to eliminate the space factor in such flights by using round-the-world flights, since then the resulting displacement in space becomes zero. But since such time travel of air passengers is combined with mandatory travel over long distances, they are not currently used. Therefore, in order to make time travel suitable for practical use, the space factor in them should be eliminated by using round-the-world flights. Then in such flights the resulting displacement in space becomes zero. And the analysis of such time travel - for example, into the past time² - leads to the conclusion that as a result of any flight around the world, the plane will essentially fly to a 'different' (but with the same name) city, since even within a day in any city many little things will inevitably change. Therefore, the space factor cannot be completely zeroed out, but it can be significantly minimized. And this will allow for truly useful time travel. Moreover, there are many such 'other' cities and they exist regardless of whether we have visited them or not. But since there is no place for these 'other' cities on the Earth explained by modern science, it is logical to conclude that our planet Earth is more complex than it is explained by modern science. Therefore, our Earth actually exists in more than three-dimensional space. Perhaps in four-dimensional space, the existence of which follows from Newton's first law.

Keywords: special theory of relativity; relativistic formulas; physical reality of imaginary numbers; Multiverses; universes and anti-universes; anti-time; external and internal time; time zones on Earth; time travel

1. Introduction: fundamental mistake of the authors of special theory of relativity

Created the 20th century by Joseph Larmor [1], Nobel laureate Hendrik Anton

Lorentz³ [2], Jules Henri Poincaré [3], Nobel laureate Albert Einstein⁴ [4], and other talented scientists, the special theory of relativity (STR) are rightly considered the outstanding scientific achievement of the 20th century due to their use of principle of relativism. However, at the beginning of the twentieth century, science lacked much of the knowledge necessary to completion of the creation of the

STR. Because of this, the missing knowledge had to be replaced with postulates that turned out to be partially incorrect. Therefore, this STR itself turned out to be largely incorrect [5]-[9].

And most importantly, all the relativistic formulas obtained in it turned out to be incorrect

$$m = \frac{m_0}{\sqrt{1 - (v/c)^2}} \quad (1)$$

$$\Delta t = \Delta t_0 \sqrt{1 - (v/c)^2} \quad (2)$$

$$l = l_0 \sqrt{1 - (v/c)^2} \quad (3)$$

¹ This is reprint of the article "Antonov A. A. 2026. Planet Earth is designed much more complex than is explained by modern scientific knowledge. Norwegian Journal of Development of the International Science. No 182".

² Because it's easier to verify this

³ Who received his Nobel Prize in Physics in 1902 for explaining the Zeeman effect.

⁴ Who received his Nobel Prize in Physics in 1921 for his services to theoretical physics and especially for his research into the photoelectric effect.

and others, in which m_0 is the rest mass of a moving body;
 m is the relativistic mass of the moving body;
 Δt_0 is the rest time of a moving body;
 Δt is the relativistic time of a moving body;
 l_0 is the rest length of a moving body;
 l is the relativistic length of a moving body.

The creators of STR made this fundamental mistake without understanding that the argument v in formulas (1)-(3) according to Newton's first law is the fourth⁵, in addition to length, width and height, spatial dimension [10]-[21]. Albert Einstein also failed to use the concept of four-dimensional space in STR. However, he managed to preserve STR by using in it the principle of not exceeding the speed of light⁶.

2. The special theory of relativity taught in physics textbooks is incorrect.

From the principle of not exceeding the speed of light, which is in fact a postulate, that this STR drew the conclusion that imaginary numbers are physically unreal. But a postulate is merely an assumption. Consequently, a conclusion drawn from a postulate is also merely an assumption, which has no evidential value. Therefore, the assertion regarding the physical unreality of imaginary numbers could simply have been called a postulate. However, the authors of the version of the STR, taught in textbooks, ignored this fact, as they needed to explain the relativistic formulas in some way. And to do so, they had to at least give the impression that the principle of not exceeding the speed of light had been proven. And since these textbooks are still used in the educational process, it follows that the goal was achieved.

Therefore, further in the article we will continue to explain that the version of STR studied in textbooks is incorrect. [22]-[54]. Let us recall that the problems of the authors of STR began from the very beginning due to their inability to explain the relativistic formulas (1)-(3) published in 1905. After all, no one would need a theory that even its creators could not explain. And relativistic physicists have still not been able to explain these formulas, since all the quantities $m(v)$, $\Delta t(v)$, $l(v)$ in these formulas in the hyper-light range of speeds $v > c$ took on values measured by imaginary numbers incomprehensible to physicists. Therefore, as not to explain relativistic formulas in the hyper-light range of speeds, the principle of the non-exceeding of the speed of light was used in the STR.

However, yet in 1897, Charles Proteus Steinmetz published [55] a theory of linear electrical circuits of alternating current, in which the imaginary resistances $-j/\omega C$ of capacitors and $+j\omega L$ of inductors were de facto recognised as physically real. This provided experimental proof of the physical reality of imaginary numbers.

Therefore, for more than half a century, the radio industry has been mass-producing frequency response meters⁸ (Fig. 1), which by their very existence prove the physical reality of imaginary

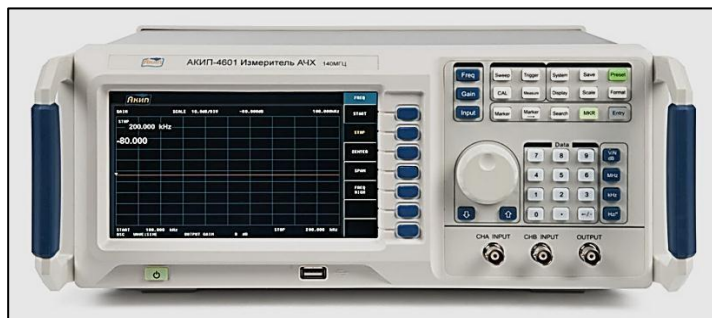


Fig. 1. In any radio engineering laboratory there are devices called frequency response meters, which already by their very existence prove the physical reality of imaginary numbers, since you can only measure what actually physically exists. And such devices measured frequency characteristics, mathematically described using imaginary numbers.

But even if any of the relativist physicists were to learn that Charles Proteus Steinmetz had already proven the physical reality of imaginary numbers, this would not save the STR. For it turns out that the relativistic formulas are not correct, since, in the superluminal speed range $v > c$, function (1) describes

⁵ Not to be confused with the fourth dimension in four-dimensional space-time (Minkowski space).

⁶ Which, as it later turned out, turned out to be incorrect. In the process of learning in science, this is natural and acceptable. But formulas that turn out to be incorrect must then be corrected. But this in STR has not been done yet.

⁷ In radio engineering and electrical engineering, the imaginary unit is conventionally denoted by the letter j , as the letter i is used to denote electric current

⁸ Also called frequency response analyzers

a physically unstable process that cannot exist in nature. Therefore, relativistic physicists did not really need any proof of the physical reality of imaginary numbers. On the contrary, in order to refuse to explain their relativistic formulas in the hyperluminal speed range $v > c$, they needed the principle of not exceeding the speed of light. And this is precisely why proof of the physical unreality of imaginary numbers was needed. However, such evidence does not exist in nature.

This is why Albert Einstein wanted to create a credible and usable version of STR. He therefore argued that there is no known physical process in nature that is described using imaginary numbers⁹. On this basis, he introduced into STR a postulate known as the principle of the non-exceeding of the speed of light. From this, it was concluded that there was no need to explain formulas (1)–(3) in the superluminal range of velocities $v > c$. And when Cherenkov radiation [56] was discovered, refuting the claim that there is no known process in physics in which anything moves at a speed exceeding the speed of light, the STR was saved by the clarification that the principle of the non-exceeding of the speed of light referred to processes in a vacuum¹⁰.

And later, at the Large Hadron Collider (costing \$10 billion), the widely publicised OPERA [57] experiment was conducted over 15 years¹¹ (between 2003 and 2018), involving over a hundred of the most eminent physics professors, the aim of which was to prove the physical reality of imaginary numbers. In 2011, the OPERA collaboration even announced the successful completion of this experiment. But six months later, at the same Large Hadron Collider, the OPERA experiment was refuted by the ICARUS experiment. This created the impression that the principle of the non-exceeding of the speed of light is irrefutable. And it is in this form that the generally accepted version of STR is now presented in all physics textbooks in all countries.

However, articles [58]–[75] have been published, including five articles in 2008–2010¹² [58]–[62], containing descriptions of radio engineering experiments that successfully proved the physical reality of imaginary numbers. Moreover, these publications also contain descriptions of well-known physical processes¹³ – a tsunami, the ringing of bells, music created by a piano, and even a swing swinging on the playground after a push from parents – proving the physical reality of imaginary numbers.

Thus we live not only in the visible and tangible world described by real numbers, but also in existing invisibl and intangible world – one far less familiar to us – described by imaginary, complex and hyper-complex numbers.

3. A corrected version of the special theory of relativity.

3.1. Corrected relativistic equations

Since we have just have proven.the physical reality of imaginary numbers in the most indisputable manner, we shall now explain formulas (1)–(3) in full. And since people tend to understand visual information better, Fig 2a,b,c show the graphs of formulas (1)–(3). As can be seen, these graphs in the sub-light speed range $v < c$ differ significantly from the graphs in the hyper-light speed range $v > c$. It therefore becomes clear that the same processes cannot occur in the sub-light and hyper-light speed ranges v . And for the same processes to occur in these ranges, the graphs of formulas (1)–(3) must be identical, as shown in Fig 2d,e,f. To achieve this, since the velocity v in formulas (1)–(3) is the fourth spatial dimension, the factor¹⁴ i^q must be introduced

$$m(q) = \frac{m_0 i^q}{\sqrt{1 - (v/c - q)^2}} = \frac{m_0 i^q}{\sqrt{1 - (w/c)^2}} \quad (4)$$

⁹ Although in fact there are many of them. And they are mentioned further.

¹⁰ And it turns out that Albert Einstein did not know about other physical processes mentioned below that prove the physical reality of imaginary numbers. Therefore, they are still not mentioned in physics textbooks.

¹¹ And for any radio engineering experiment proving the physical reality of imaginary numbers, one day is more than enough for one engineer

¹² That is, even before the publication in 2011 of the message about the supposedly successful completion of the OPERA experiment

¹³ Contrary to Albert Einstein's assertion that there are no processes in nature that can be described using imaginary numbers,

¹⁴ In the theory of functions of a complex variable, the function i^q is defined only for integer values of the argument q . However, his definition can to be extended as follows. For integer values of the argument ... $-2, -1, 0, +1, +2, +3, +4, +5, \dots$ the function i^q is equal to ... $-1, -i, +1, +i, -1, -i, +1, +i, \dots$ But for the same integer values of the argument ... $-2, -1, 0, +1, +2, +3, +4, +5, \dots$ the same values ... $-1, -i, +1, +i, -1, -i, +1, +i, \dots$ is also equal to the function $e^{iq\pi/2}$, which, in accordance with Euler's formula $e^{iq\pi/2} = \cos(q\pi/2) + i\sin(q\pi/2)$, is defined also for non-integer values of the argument q . Therefore, definition of the function i^q can be extended to any values of the argument q by the formula $i^q = \cos(q\pi/2) + i\sin(q\pi/2)$, analogous to Euler's formula. The resulting formula will allow the value of the function i^q to be determined for any values of the argument q , including non-integer values. And it will be required in astro-geophysical studies of portals, which will be discussed further on.

$$\Delta t(q) = \Delta t_0 i^q \sqrt{1 - (v/c - q)^2} = \Delta t_0 i^q \sqrt{1 - (w/c)^2} \quad (5)$$

$$l(q) = l_0 i^q \sqrt{1 - (v/c - q)^2} = l_0 i^q \sqrt{1 - (w/c)^2} \quad (6)$$

where $q(v) = \lfloor vq/c \rfloor$ – the “floor” function from discrete mathematics defined for the argument vq/c which constitutes the fourth spatial dimension;

$w = v - qc$ – the velocity that is local to all universes.

And since the fourth spatial dimension v is a vector quantity, the formulas (4)–(6) must be revised once again. To this end, three factors i^q , i^r and i^s must be introduced into formulas (4)–(6)

$$m(q, r, s) = \frac{m_0 i_1^q i_2^r i_3^s}{\sqrt{1 - [v/c - (q + r + s)]^2}} \quad (7)$$

$$\Delta t(q, r, s) = \Delta t_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (8)$$

$$l(q, r, s) = l_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (9)$$

where $q(v) = \lfloor v_q/c \rfloor$ – the “floor” function in discrete mathematics of the argument v_q/c , which

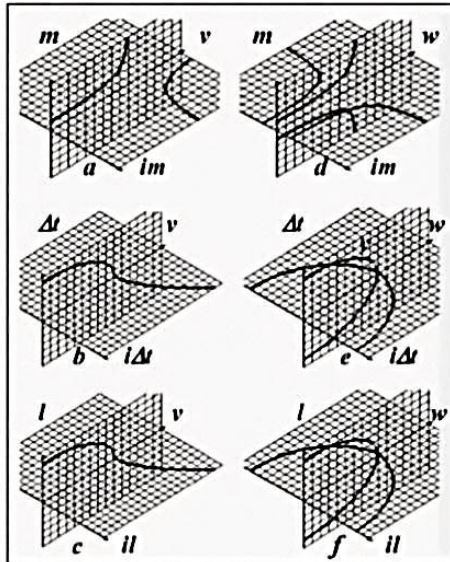


Fig. 2. Graphs of the functions $m(v)$, $\Delta t(v)$ and $l(v)$ corresponding to the existing and corrected versions of the STR in the subluminal $v < c$ and superluminal $v > c$ velocity ranges

is one of the orthogonal coordinates q of the fourth spatial dimension v ;

$r(v) = \lfloor v_r/c \rfloor$ – the “floor” function of discrete mathematics of the argument v_r/c , which is the other orthogonal coordinate r of the fourth spatial dimension v ;

$s(v) = \lfloor v_s/c \rfloor$ – the “floor” function of discrete mathematics of the argument v_s/c which is yet another orthogonal coordinate s of the fourth spatial dimension v ;

v_q, v_r, v_s – projections of the velocity vector v onto the orthogonal co-ordinates q, r, s (see Fig. 3).

This function i^q (as well as the functions i^r and i^s) in formulas (7)–(9), which defines the

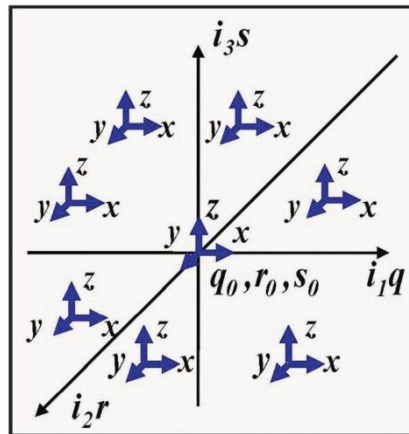


Fig.3. The six-dimensional space of the hidden Multiverse, where q, r, s are the coordinates of mutually invisible parallel universes and anti-universes, and x, y, z are the coordinates of the material content of these parallel universes and anti-universes

nature of each universe, for integer values of the argument $q(v)$, equal to ... 0, 1, 2, 3, 4, 5, ..., successively takes the values ..., +1, +i, -1, -i, +1, +i, ... and so on. Its value¹⁵ $q(v) = 0$ in formulas (7)–(9) for the sublight speed range $v < c$ corresponds (since $i^0 = 1$) to our visible universe, which we shall call the tardion¹⁶ universe. The value $q(v) = 1$ in the superluminal speed range $2c > v > c$ corresponds (since $i^1 = i$) to some other, already invisible universe, as it located beyond the event horizon. We shall therefore call it the tachyon¹⁷ universe. Then the value $q(v) = 2$ in the velocity range $3c > v > 2c$ will correspond (since $i^2 = -1$) to an invisible tardion anti-universe. The value $q(v) = 3$, in the velocity range $4c > v > 3c$, will correspond (since $i^3 = -i$) to an invisible tachyon anti-universe. The value $q(v) = 4$ in the speed range $5c > v > 4c$ will correspond (since $i^4 = +1$) to another (and therefore also invisible) tardion universe. The value $q(v) = 5$ in the velocity range $6c > v > 5c$ will correspond (since $i^5 = +i$) to another tachyon universe. And so on.

Consequently, nature contains not only our visible universe, which, as stated in the generally accepted version of STR, corresponds to formulas (1)–(3) but also a multitude of other mutually invisible¹⁸ universes and anti-universes that correspond to formulas (7)–(9). And these mutually invisible universes and anti-universes, together with our visible universe, form an invisible Multiverse [76]–[84], which we have therefore called the hidden Multiverse.

3.2. Explanation of the phenomena of dark matter and dark energy by the existence of universes and anti-universes of the hidden Multiverse

Therefore, having explained the meaning of the basic concepts we need, it would seem that it is time to find out what the structure of the hidden Multiverse is. However, at present, no explanation of the structure of the Multiverse can be considered convincing unless it explains the phenomena of dark matter and dark energy [85]–[90], discovered in the XX century. Which are so called because of their incomprehensibility, as not a single chemical element has been detected in them, and also because they do not emit, absorb, reflect, or refract electromagnetic radiation and, therefore, are invisible. Besides, the persistent search for dark matter and dark energy, which account for more than 95% of all mass-energy contained in the hidden Multiverse, at the Large Hadron Collider exclusively in the microcosm of our only visible universe also seems inconsistent with common sense.

More consistent with common sense would be the assumption that dark matter and dark energy [91]–[95] are all except our visible universe, the mutually invisible universes and the antiuniverses of the hidden Multiverse. Then dark matter is the invisible universes and antiuniverses neighboring our visible universe, and dark energy is the remaining invisible universes and antiuniverses of the hidden Multiverse. Therefore, the phenomena of dark matter and dark energy will be a gravitational shadow¹⁹ on our visible universe from the remaining mutually invisible universes and antiuniverses included in the hidden Multiverse. This assumption explains all the incomprehensibility of the phenomena of dark matter and dark energy simply and clearly. That's why we will use it.

Then, assuming that over the billions of years of its existence, the mass-energy of all universes and

¹⁵ If we start counting the value of q from our visible universe.

¹⁶ The term "tardion universe" is borrowed from Isaac Asimov's short story "Take a Match."

¹⁷ The term "tachyon universe" is borrowed from Isaac Asimov's short story "Take a Match."

¹⁸ Because they are all beyond the event horizon

¹⁹ And therefore, like our shadow on a sunny day, they do not contain a single chemical element..

anti-universes of the hidden Multiverse, due to the presence of a huge number of portals between them according to the law of communicating vessels, has been largely averaged, it becomes possible, using the data obtained by the WMAP and Planck spacecraft, to determine the structure of the hidden Multiverse. And according to data obtained by the WMAP spacecraft [96], the mass-energy of our visible universe (actually, our hidden Multiverse) consists of 4.6% baryonic matter, 22.4% dark matter and 73.0% dark energy. And according to more recent data obtained by the Planck spacecraft [97], the mass-energy of our visible universe (again, actually, our hidden Multiverse) consists of 4.9% baryonic matter, 26.8% dark matter and 68.3% dark energy. As you can see, these data differ little from each other, which proves their truth. Therefore, it is permissible to assert that:

- our hidden Multiverse according to experimental data obtained by the WMAP spacecraft, it consists of $100\% / 4.6\% = 21.8^{20}$ parallel universes and anti-universes, and according to data obtained by the Planck spacecraft, it consists of $100\% / 4.9\% = 20.4$ parallel universes and anti-universes;
- dark matter, according to experimental data obtained by the WMAP spacecraft, consists of $22.4\% / 4.6\% = 4.9$ parallel universes and anti-universes, and according to data obtained by the Planck spacecraft, it consists of $26.8\% / 4.9\% = 5.5$ parallel universes and anti-universes;
- dark energy, according to experimental data obtained by the WMAP spacecraft, consists of $73.0\% / 4.6\% = 15.9$ parallel universes and anti-universes, and according to data obtained by the Planck spacecraft, it consists of $68.3\% / 4.9\% = 13.9$ parallel universes and anti-universes;
- and our visible universe, of course, is only one.

3.3. The structure of the hidden Multiverse

Fig. 4 shows an example, corresponding to the results of calculations of the possible structure of the hidden Multiverse. In this structure of the hidden Multiverse, the distribution of material content in each invisible universe and anti-universe will be determined by some function $f_{q,r,s}(x, y, z)$, and the coordinates of these universes will be determined by the quantities i_1q, i_2r, i_3s . Those. such a hidden Multiverse will be six-dimensional and it will be described by the quaternion $f_{q,r,s}(x, y, z) + i_1q + i_2r + i_3s$, in which the imaginary units i_1, i_2, i_3 are related by the relations [98]-[100]

$$i_1^2 = i_2^2 = i_3^2 = -1 \quad (10)$$

$$i_1i_2i_3 = i_2i_3i_1 = i_3i_1i_2 = -1 \quad (11)$$

$$i_1i_3i_2 = i_2i_1i_3 = i_3i_2i_1 = 1 \quad (12)$$

²⁰ Naturally, the number of universes and anti-universes is an integer, and a non-integer number was obtained only due to experimental errors, including due to failure to take into account unknown factors influencing the result of the experiment.

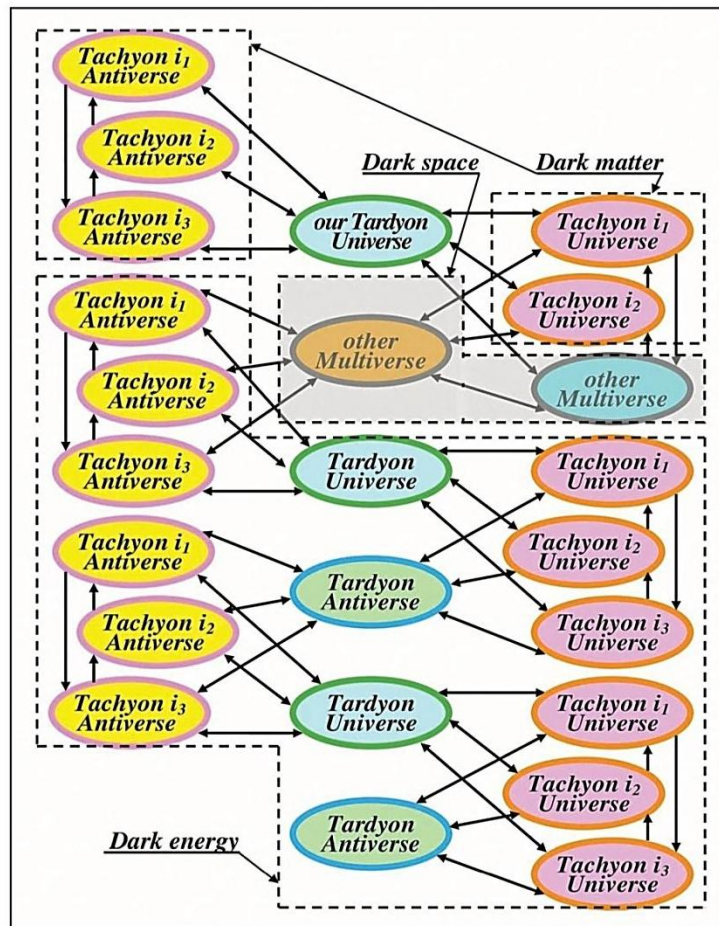


Fig. 4. An example of the structure of the hidden Multiverse, corresponding to the principle of physical reality of hypercomplex number

This is exactly what Lisa Randall predicted²¹: "We may be living in a three-dimensional pocket of higher-dimensional space."

From formulas (10)-(12) it follows that such a hidden Multiverse has a helical structure, and its mutually invisible universes and anti-universes (in addition to our visible universe) form dark matter and dark energy. In this case, it is possible to move into the tardion anti-universe from the tardion universe and into the tardion universe from the tardion anti-universe in various, but not arbitrary, ways, but only in such a way (see Fig. 4), in which the value of i^n will successively take the values $\dots +1, +i_1 \oplus i_2 \oplus i_3, -1, -i_1 \oplus i_2 \oplus i_3, +1, \dots$ and etc., where $\oplus$ is the symbol of the logical operation of discrete mathematics 'exclusive OR'. In this case, different trajectories of movement from one universe (or anti-universe) to another can differ only due to the replacement of some tachyon universes from i_1, i_2, i_3 with others and some tachyon anti-universes from i_1, i_2, i_3 with others. Consequently, tachyon universes i_1, i_2, i_3 in the hidden Multiverse are located parallel to each other. Tachyon anti-universes i_1, i_2, i_3 are also located parallel to each other for the same reasons. And therefore, in the hidden Multiverse, when transitioning from any tardion universe to a tardion anti-universe and then to another tardion universe, parallel universes and antiverses must alternate in the following sequence - 'tardion universe', 'one of the tachyon universes', 'tardion anti-universe', 'one of the tachyon anti-universes', 'tardion universe', 'one of tachy-universes', etc.

Moreover, portals in such a structure of the Multiverse are not only bidirectional, corresponding to formula (10) and shown by two-way arrows, but also unidirectional, corresponding to formulas (11), (12) and shown by one-way arrows. And since the structure of our hidden Multiverse, as shown in Fig. 4, is open in some places, then in these places it is connected to other Multiverses through the corresponding portals. And all together they collectively form the Hyperuniverse.

3.4. How can we be convinced of the real physical existence of invisible universes and anti-universes?

²¹ Lisa Randall is a professor in the Department of Physics at Harvard University and a member of the American Academy of Arts and Sciences and also the National Academy of Sciences of the United States.

However, in science, any evidence, even the most seemingly impeccable one, can be trusted only if it is confirmed experimentally. And such experimental evidence of the existence of invisible parallel universes²² and anti-universes shown in Fig. 4 adjacent to our visible universe can be more than two hundred thousand anomalous zones [101]-[104], existing on Earth, serving as entrances to portals leading to planets of various star systems. Most of the portals probably lead to astronomical objects in our universe and even in our solar system. A smaller number of portals connect us with other universes and anti-universes of the hidden Multiverse. And, perhaps, some portals even connect us with astronomical objects in other Multiverses of the Hyperverses. All these possible options in Fig. 4 are shown. The classification of anomalous zones after astro-geophysical studies of the corresponding portals will help determine where each portal leads.

And the possible distrust of the claim that anomalous zones are entrances to portals can presumably be eliminated by astronomical observations [105]-[122] of the star sky in anomalous zones. This would require comparing on computer of maps of the starlit sky observed in anomalous zones and somewhere outside of anomalous zones. Into the bargain some observatories are already in anomalous zones. For example, the Main Astronomical Observatory of the National Academy of Sciences of Ukraine, which is located 12 km from the center of its capital, Kyiv in Goloseyevo Forest. And if such differences are found, it is evidence that the corresponding portal to this anomalous zone leads to another planet in our solar system or further afield. After all, the starry sky is different for every planet.

4. Time Travel on Earth

4.1. Where are the anti-matter and the anti-time located?

And now we can explain the unexplained in textbooks of physics problem - where is the antimatter, whose existence these textbooks do acknowledge but at the same time explain that in our only visible universe it cannot exist because of its inevitable annihilation with matter. However, it exists.

However, antimatter exists. In 1995, scientists at CERN carried out a sensational experiment that produced nine antihydrogen atoms that existed about 40 billionths parts of a second. And just one gram of such an antihydrogen would have cost \$662.5 trillion. So the existence of antimatter has even been proven experimentally. But where does it exist then? After all, in all physics textbooks it is claimed that in nature exists our only visible universe. Therefore, the experiment at CERN can also be considered as proof that the version of the STR studied in textbooks is incorrect.

And in accordance with formulas (7)-(9) of the corrected version of STR, anti-matter in nature exists in the invisible tardyon and tachyon anti-universes of the hidden Multiverse. Moreover, in these invisible tardyon and tachyon anti-universes, anti-time and anti-space [105]-[122] also exist.

4.2. Time Travel on Earth, Inner Time and Outer Time

The existence of anti-time makes it possible in accordance with interconnected formulas (2), (3); (5), (6) and (8), (9) due to travel in space also time travel. But since neither the portals, much less the universes and anti-universes of the hidden Multiverse, are still completely unexplored, time travel in space is now inaccessible to us. Therefore, further we will consider only the possibility of time travel on Earth [10]-[21]. Moreover, the presence of time zones on Earth also makes time travel possible through space travel. However, although official modern science allows the possibility of time travel in some exotic situations in the special²³ and general²⁴ theories of relativity, it still claims that time travel of people on Earth, either now or in the distant future, will never be possible.

Nevertheless, such time travels of people on Earth is now became accessible by travels on airplanes, as upon landing at any airport, millions of air passengers always reset their watches to a local time of the arrival airport. This confirms their time travels and disproves the erroneous assertions of the incorrect version of special relativity taught in physics textbooks.

And when explaining time travel on Earth, it is necessary to take into account the existence in nature, in addition to internal time, which we always use, also external time, which we have never used before. And which are generated by different circumstances and have different characteristics. Internal time can be called biological human time, since one second is one contraction of the human heart. And therefore it cannot flow backwards.

External time is determined by processes occurring in the external environment. Namely, the rotation of the Earth and the existence of time zones. These features of it are reflected in one more formula, absent from physics textbooks, derived from the relativistic formulas of STR (2), (3); (5), (6) and (8), (9)

²² I.e. such that do not intersect

²³ For example, in the "twin paradox"

²⁴ For example, in the ultra-high gravity region of a black hole's event horizon

$$\Delta t = \Delta t_0 \, l / l_0 \quad (13)$$

in which Δt is external time in hours;

Δt_0 is 24 hours;

l is path length in the direction perpendicular to time zones;

l_0 is the length of a circle that intersects 24 time zones at a given latitude, which are generated by the rotation of the Earth around its axis.

These two different times also have different properties. Human biological time cannot flow backwards. A person cannot return to his youth or childhood. And in external time on Earth, an airplane can fly across time zones both to the west and to

Table 1. Examples of business jet characteristics that can be used for time travels

Aircrafts	Maximum range	Cruising speed	Hourly rates	Seats
Citation Latitude	5 300 km	815 km/h	3 500 €/hour	8
Citation Longitude	7 400 km	910 km/h	5 000 €/hour	12
Challenger 300	5 700 km	850 km/h	4 900 €/hour	8
Challenger 350	5 926 km	850 km/h	4 000 €/hour	9
Challenger 600	5 500 km	850 km/h	4 600 €/hour	12
Challenger 3500	6 297 km	985 km/h	5 500 €/hour	10
Falcon 20	4 200 km	987 km/h	3 900 €/hour	8
Falcon 50/50EX	5 600 km	850 km/h	4 900 €/hour	8-10
Global 5500	10 927 km	900 km/h	8 000 €/hour	16
Gulfstream G150	5 200 km	850 km/h	3 900 €/hour	6-8
Gulfstream G200	5 000 km	870 km/h	6 200 €/hour	8
Hawker 850 XP	4 800 km	750 km/h	3 400 €/hour	6-8
Hawker 900XP	5 400 km	865 km/h	3 700 €/hour	6-8
Hawker 4000	5 280 km	890 km/h	5 400 €/hour	10
Learjet 70	3 815 km	967 km/h	3 500 €/hour	7
Legacy 450	5 370 km	860 km/h	3 300 €/hour	8
Praetor 600	7 400 km	850 km/h	6 000 €/hour	12

Table 2. The value of external time at different latitudes

Location of departure and arrival airfields	Geographic coordinates of the airfield	Size of 24 time zones for a round-the-world flight	Size of one time zone.
Santiago de Chile	33,45° S.	33422 km	1393 km
Buenos Aires	34,60° S.	33021 km	1375 km
Melbourne	37,82° S.	31339 km	1306 km
New York City	40,72° N.	30456 km	1269 km
Reykjavík (Iceland)	64,15° N.	17616 km	734 km
Murmansk (Russia)	69,58° N.	14424 km	601 km
Kirkenes (Norway)	69,73° N.	14376 km	599 km
Longyearbyen (Spitsbergen, Norway)	78,13° N.	8184 km	341 km
Alert, (Canada)	82,5° N.	5230 km	218 km

the east. But in the external environment it is possible to move both into the past and into the future. Moreover, even short-term movements in external time can some-times be very useful. This is known to everyone, although it has not yet been used in any way in creative human activity. And this is a resource given to us by nature for solving the problem of people traveling through time, which even would seem easy to use (you just need to fly on an airplane).

And although time travels on Earth is not currently used by humans because of the associated space travels, this problem is quite solvable. To do this, the aircrafts must make a round-the-world trips around the north or south pole and land after 24 hours of outside time at the same aerodromes from which the journeys began. Thereby eliminating the presence in time travels of the factor of space which is reset to zero due to such a flight



Fig. 5. One of the business jets

And there are many aircraft models suitable for use in time travel. They are called business jets²⁵ (see Fig. 5). There are currently 22000-24000 business jets in operation on Earth. Table 1 shows the flight performance characteristics of some business jets. And Table 2 shows airfields quite close to the North Pole²⁶ that can provide the shortest routes for round-the-world flights.

Moreover, time travel can be accomplished not only on airplanes. Time travel on airplanes is only needed if a person needs to travel to the past or future. And if it is necessary to receive or transmit information to the past or future, then radio communications can be used using round-the-world communication lines²⁷.

4.3. The structure of planet Earth differs from the structure corresponding to modern scientific knowledge

Thus, time travel on Earth is physically possible and is currently already technically feasible [141]-[151], since there are suitable aircraft models necessary for this and acceptable flight routes. However, neither business jets nor other aircraft have ever made flights round-the-world, because there was no need for them. Indeed, any airfield, the most distant from the airfield from which any aircraft took off, is located where its antipodes are located, that is, at a diametrically opposite point on Earth. But this is only half of the trip around the world. Therefore, there was no need for longer flights. The distances to other airfields are shorter. And because of this, the features of round-the-world flights are completely unknown to us. Now they must be studied in the process of actual flights around the world.

And since, dear reader, neither the author, nor you, nor anyone else has ever flown round-the-world, let's make such an imaginary journey through time. Let's say you fly from London to New York and after landing you set your watch back 5 hours. Then you flew from New York to Tokyo and after landing you set your clocks back another 11 hours. Finally, after landing in Tokyo, you boarded a plane bound for London. And after landing in London, you set your clock back another 8 hours. Thus, ultimately you will travel in external time into the past by $5 + 11 + 8 = 24$ hours, i.e. for a day. Consequently, this journey in external time was round-the-world, But all the flights you took were regular commercial ones. And your travels did not cause any surprise among air passengers, since no one knew anything about them. However, you have moved back 24 hours, i.e. a day into the past.

And we ended up back in London. But at a different time. You were convinced of this by buying a newspaper. Moreover, the newspaper seller knew nothing about the present time from which you arrived. None of the passers-by knew about this either. Then you called himself home. And you talked to ourselves. After all this, making sure that you really visited yesterday's London, you took return flights London-Tokyo, Tokyo-New York and New York-London to today's London. And, having convinced yourself of the feasibility of time flights, you inevitably asked yourself the question - where is this yesterday's London, about which no one knows anything, located? After all, in this London of yesterday you did not find your apartment. In its place was the same apartment, but your double from yesterday lived in it. Therefore, another London and a whole other world really exist. But it is not on any geographical map. So where on our Earth is it located?

Such time travel creates situations completely incomprehensible to current human knowledge and life experience. Although, observing the arrivals of different planes at the airport at different times, we will never see any problems in communication between passengers arriving on these planes, as well as with the people who met them, due to the difference in arrival times. Nevertheless, it is clear that for residents of, for example, London, who are in today's and yesterday's time, the material reality surrounding them will be different. Somewhere in yesterday's London, unlike today's London, a new subway station has not yet been opened, your car has not yet been repaired and something else has not yet been done. Therefore, today's London and yesterday's London are not compatible either in space or in time, since they differ in many small details. Moreover, these two different Londons, in one of which the one plane took you to, and the plane took you from the other plane exist on Earth regardless of whether you flew into them or not. Therefore, another world in which other Londons exist and other other cities exist. But where? Naturally, on our Earth. Then it is obvious that our planet Earth is not like the globe that we and modern science imagine it to be. Other way round it is some kind of three-dimensional (i.e. volumetric) spiral structure. Using most likely the same fourth spatial dimension that was mentioned at the beginning of the article And science will now have to take up the study of this other world.

²⁵ A business jet is a small private jet aircraft for transporting a limited number of passengers (usually from 6 to 20) on an individual order for businessmen, officials and VIPs; it is characterized by a higher level of comfort, the ability to take off/land from small airfields and high speed, allowing you to quickly get to anywhere in the world

²⁶ Since the existing airfields are further from the south pole. But, probably, such airfields can be created in Antarctica.

²⁷ But also with its transmission around the north or south pole.

Nevertheless, in any case, using around-the-world flights (if the Earth's structure is as modern science believes) or quasi-around-the-world flights (if the Earth's structure is different), time travel is feasible. We have seen this for yourself. And then it will become possible to foresee catastrophes, accidents, bankruptcies, marital infidelity, criminal activity, and much more. And therefore, somehow, it will be possible to avoid them or otherwise minimize the unpleasant consequences associated with them. Since we will now exist not only in today's time but also in yesterday's and tomorrow's time, we will be able to make my life much more successful by communicating with our doubles. Presumably, it will even now be possible to bring back to life people who died in accidents or as a result of crimes²⁸.. And now, thanks to the increasing information transparency of human activity, any immoral and criminal manifestations will gradually disappear. Much more will happen, too, something that is hard to believe now.

5. Conclusion

Thus, the really existing physical world turned out to be in many ways different from the way it is explained in the version of STR studied in physics textbooks. However, although over the past hundred years since the creation of this STR, much has been refuted, the content of the sections of physics textbooks that present it has not essentially changed. Its main difference from pre-existing classical physics is its use of the principle of relativism. But all the formulas obtained in STR using the principle of relativism nevertheless turned out to be incorrect. And even the creators of this theory themselves could not explain them. Moreover, these formulas are still not correctly explained in textbooks, since their explanation using an incorrect postulate, called the principle of not exceeding the speed of light, is incorrect.

Therefore, Albert Einstein, in his version of STR, in order to make it explainable, it was necessary to prove not physical reality, but, on the contrary, the physical unreality of imaginary numbers. And for this it was necessary that this physical unreality of imaginary numbers should follow from something indisputably true. And as such an initial supposedly indisputably truth, a postulate was used, called the principle of not exceeding the speed of light. At the same time, And Albert Einstein ignored the fact that in fact there are many well-known processes in nature – tsunamis, Indian summers, bell ringing, music created by a piano, and even swings swinging on the play-ground after a push from parents – proving the physical reality of imaginary numbers. Obviously he didn't know about it.

This line of reasoning ignored the fact that Charles Proteus Steinmetz, back in 1897 [\$\$], i.e. even before the creation of the special theory of relativity, had already essentially proven the physical reality of imaginary numbers in his proposed interpretation of Ohm's law. His theory asserted that the imaginary resistances $-j/\omega C$ of capacitors and $+j\omega L$ of inductors actually physically exist. Since then, radio engineers have never had the slightest reason to doubt the truth of this assertion, since changing the frequency of a sinusoidal voltage applied to any LCR-circuit always changes the magnitude of the current flowing through it. This fact, encountered literally at every step in the practical work of radio engineers, is an extremely simple, absolutely understandable, and irrefutable proof of the physical reality of imaginary numbers.

Nevertheless, Albert Einstein, in his version of STR, needed to somehow doubt this. Other-wise, he would have to admit that the creators of this version of STR cannot explain the obtained relativistic formulas in the hyperluminal speed range $v > c$. And then this theory, which even its creators could not explain, would naturally turn out to be of no use to anyone. That is why a postulate was introduced into the STR, called the principle of not exceeding the speed of light, from which a conclusion was made about the physical unreality of imaginary numbers, which was not confirmed by any experiments. This made it possible not to explain relativistic formulas in the hyperluminal speed range $v > c$. Therefore, despite the fact that Albert Einstein was nominated for the Nobel Prize 66 times for the creation of STR, due to the lack of any experimental evidence of its truth, he never received it for his version of this theory.

But in order to save the denial of the physical reality of imaginary numbers in the incorrect version of special relativity, relativistic physicists had to make very large and expensive efforts

In particular, to create at least illusion of the impossibility of refuting the STR's assertion of the physical unreality of imaginary numbers, on the Large Hadron Collider (worth ten billion dollars) a collaboration OPERA, which included more than one hundred of the most authoritative professors-physicists, for almost 15 years (2003-2018) was the unsuccessful physical experiment OPERA, which aimed to prove the physical reality of imaginary numbers but failed to do so.

And thereby supposedly proved the impossibility of refuting the assertion about the physical unreality of imaginary numbers. In 2011, it was even announced that the OPERA experiment had been sensationally successful, but then half a year later in 2012, the OPERA experiment was refuted by another

²⁸ Perhaps President Kennedy could have been saved in a similar way after the assassination attempt [152]-[162].

ICARUS experiment on the same Large Hadron Collider

Therefore, physicists are still ignoring publications that cite simple and comprehensible radio-technical experiments successfully proving the physical reality of imaginary numbers and explaining that if the imaginary numbers were, as claimed in the incorrect version of STR, physically unrealistic, there should be no radio nor computer technics.

Moreover, because of the assertion of the physical unreality of imaginary numbers and thus of the existence in nature of our only visible universe, it has become apparent that there was no place for anti-matter and tachyons in this only visible universe. Although their existence in nature was not denied. And where they are located is explained only by the corrected version of the corrected version of STR.

It also transpired that, because of the assertion of the physical unreality of imaginary numbers and therefore of the existence in nature of our only visible universe, the phenomena of dark matter and dark energy had never been and would never be explained, because the dark matter and dark energy are, according to the corrected version of the STR, all reciprocally invisible universes and anti-universes existing outside our visible universe in the hidden Multiverse.

More than 200,000 anomalous zones have been discovered on Earth, which are entrances of portals to the planets of not only our Solar System, but also other star systems in the hidden Multiverse and even in the Hyperverses. And it also proves the existence of other universes and anti-universes. Moreover, in the existence of these invisible outside the portals of universes and anti-universes can be ascertained by astronomical observations of the star sky in portals. But these low-cost astronomical observations, which would allow for sensational scientific discoveries of other universes and anti-universes, are still not being made, probably because of the fear that invisible neighboring universes and antuniverses ones will be discovered. And then the version of the STR studied in textbooks on physics would have to be undeniably disbelieved.

The version of STR taught in physics textbooks also leads to the conclusion that time travel is impossible for humans. Although, in fact, millions of air passengers already make such time travel every day, as evidenced by the fact that passengers of planes reset their clocks to local time after landing. However, since such time travel by air passengers occurs simultaneously with long distances travel, it is currently not used. The article explains how, through quasi-round-the-world flights, time travel may become physically and technically feasible. Less-expensive radiotelephone time travel is also possible, and once it's in demand, it could be implemented quickly and inexpensively. This would make it possible to communicate and exchange information with people (including oneself) in the past or future relative to our own time.

And, finally, such quasi-round-the-world time travel will prove that our Earth is much more complex than is explained by modern science. It is probably a three-dimensional spiral structure²⁹ in four-dimensional space, the existence of which follows from Newton's first law.

References

1. Larmor J.J. (1897). *A Dynamical Theory of the Electric and Luminiferous Medium. Part III. Relations with Material Media*. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 190, 205-300.
2. Lorentz H.A. (1899). *Simplified Theory of Electrical and Optical Phenomena in Moving Systems*. Proceedings of the Netherlands Academy of Arts and Science. Amsterdam. 1, 427-442.
3. Poincaré H. (1905). *On the Dynamics of the Electron*. Comptes Rendus. 140. 1504-1508.
4. Einstein A. (1905). *Zur Elektrodynamik bewegter Körper*. Annals of Physic. 17. 891-921.
5. Terletsky Ya. P. (1966). *Paradoxes of the theory of relativity*. Nauka Publishing House. Moscow. (In Russian)
6. Logunov A. A. (1987). *Lectures on the theory of relativity and gravitation*. Nauka Publishing House. Moscow. (In Russian)
7. Atsyukovsky V. A. (2003). *General ether dynamics*. Energoatomizdat. Moscow. (In Russian)
8. Kalinin S. A. (2003). *Einstein's cardinal errors*. Editorial Urss Publishers. Moscow. (In Russian)
9. Arteha S. H. (2007). *Critique of the foundations of the theory of relativity*. 2nd ed. LKI Publishing House. Moscow. (In Russian)

²⁹ A one-dimensional (in the form of a line) spiral in two-dimensional space (for example, on a sheet of paper) is, for example, the well-known Archimedes spiral. Two-dimensional (in the form of a tape) Archimedes spiral in three-dimensional space are, for example, a medical bandage and a medical plaster. And our Earth is supposedly a three-dimensional Archimedes spiral made in a similar way in four-dimensional space, the existence of which follows from Newton's first law.

10. Antonov A. A. (2025). *Time Travels are Already Possible Nowadays*. *European Journal of Applied Sciences. Services for science and education*. U.K. 13(03). 47-70. DOI:10.14738/aivp.1303.18764.
11. Antonov A. A. (2025). *Time travels are already possible for people on Earth*. *German International Journal of Modern Science*. 104. 64-76. DOI: 10.5281/zenodo.15480577
12. Antonov A. A. (2025). *Discovery of the possibility for people on Earth of time travels*. *Norwegian Journal of development of the International Science*. 156. 84-98. <https://doi.org/10.5281/zenodo.15397809>
13. Antonov A. A. (2025). *The discovery of physically real time travels*. *Journal of Science*. Lyon. 66. 33- 48. <https://doi.org/10.5281/zenodo.15584655>
14. Antonov A. A. (2025). *The physical reality of time travels available to people*. *Annali d'Italia*. 67. 58-72. DOI: 10.5281/zenodo.15545211
15. Antonov A. A. (2025). *The physical possibility for people on Earth of time travel*. *The scientific heritage*. 163. 44-58. DOI: 10.5281/zenodo.15728017
16. Antonov A. A. (2025). *Proof of the physical reality of time travels available to humans*. *Danish Scientific Journal*. 96. 72-86. <https://doi.org/10.5281/zenodo.15553087>
17. Antonov A. A. (2025). *Discovery of the possibility for people on Earth of time travels*. *International independent scientific journal*. 74. 37- 52.
18. <https://doi.org/10.5281/zenodo.15634030>
19. Antonov A. A. *Time travels is now physically possible*. XX international scientific conference "The modern vector of the development of science". Philadelphia. USA. 12-13.06.2025. DOI <https://doi.org/10.5281/zenodo.15691366>
20. Antonov A. A. *The physical possibility for people on Earth of time travels*. *Polish journal of Science*. 87. 39-53. DOI: 10.5281/zenodo.15700637
21. Antonov A. A. *Time travels is now physically possible*. XVI international scientific conference "Theoretical and practical perspectives of modern science". Stockholm. Sveden. 27-28.05.2025. DOI <https://doi.org/10.5281/zenodo.15577281>
22. Antonov A. A. *The discovery of physical possibility of time travels*. II International Scientific Conference "Expanding knowledge through interdisciplinary research". Sydney. Australia. 15-16.05.2025.2. DOI <https://doi.org/10.5281/zenodo.1549756>
23. Antonov A.A. (2021). *The special theory of relativity stated in physics textbooks is incorrect*. 77th International Scientific Conference of the Eurasian Scientific Association "Theoretical and practical issues of modern science". Moscow. ESA. 11-15. (In Russian)
24. Antonov A. A. (2021). *Version of the special theory of relativity that is studied in all physics textbooks is incorrect*. *Österreichisches Multiscience Journal (Innsbruck, Austria)*. 43(1). 17-22. <http://osterr-science.com>
25. Antonov A. A. (2021). *The fallacy of the STR version studied in physics textbooks proved experimentally*. *Österreichisches Multiscience Journal (Innsbruck, Austria)*. 45(1). 17-26.
26. Antonov A. A. (2021). *Generally accepted version of the special theory of relativity contained in physics textbooks is incorrect*. *The scientific heritage*. (Budapest, Hungary). 7 3(2). 39-43. DOI:19.24412/9215-0365-2021-73-2-39-43
27. Antonov A. A. (2021). *Special theory of relativity presented in physics textbooks is wrong*. *Norwegian Journal of development of the International Science* 68(1). 3-7. DOI: 10.24412/3453-9875-2021-68-3-7.
28. Antonov A. A. (2021). *In all physics textbooks an erroneous version of special theory of relativity is given*. *International independent scientific journal*. 31.34-39. <http://www.iis-journal.com>
29. Antonov A. A. (2021). *All physics textbooks study incorrect special theory of relativity*. *Sciences of Europe*. (Praha, Czech Republic) 79(1). 30-35. DOI: 10/24412/3162-2364-2021-79-30-35
30. Antonov A. A. (2021). *Special theory of relativity, which is studied in physics textbooks, is incorrect*. *German International Journal of Modern Science*. 16, 49-53. DOI: 10.24412/2701-8369-2021-16-49-53
31. Antonov A. A. (2021). *Special theory of relativity, which is studied in all physics textbooks, is incorrect*. *Danish Scientific Journal*. 51(1). 31-35. <http://www.danish-journal.com>
32. Antonov A. A. (2021). *Special theory of relativity taught in all physics textbooks is incorrect*. *Annali d'Italia*. 22(1). 39-44. <https://www.anditalia.com/>
33. Antonov A. A. (2021). *Special theory of relativity taught in physics textbooks is wrong*. *Journal of science*. Lyon. 23. 47-52. <https://www.joslyon.com/>

34. Antonov A. A. (2021). *Experimental proofs of infidelity of the version of the special theory of relativity studied in physics textbooks and the truth of its alternative version*. 80th International Scientific Conference of the Eurasian Scientific Association "Development of science and education in the conditions of world instability". Moscow. ESA. 8-17. <https://esa-conference.ru/sborniki/?y=2021> (In Russian)
35. Antonov A. A. (2021). *Experimental evidences for the fallacy of the STR version in the physics textbooks*. European Journal of Applied Sciences. Services for Science and Education. UK. 9(6). 349-364. DOI:10.14738/aivp.96.11304.
36. Antonov A. A. (2021). *If the STR version in physics textbooks were true, we would never have heard the music of the piano and the bell ringing, there would be no television, no cellular telephony, no radar or GPS navigation, we would not even be aware of the existence of resonance and Ohm's law as interpreted by Steinmetz, and our children could not swing on the swings*. The scientific heritage (Budapest, Hungary). 78(2). 41-50. DOI: 10.24412/9215-0365-2021-78-2-41-50
37. Antonov A. A. (2021). *The STR version in physics textbooks must be corrected, because if it were true, there would be no tsunamis or indian summer in nature, we would be never have heard piano music, engineers would be not have been able to create television, cell phones, GPS trackers, and even children would not be able to swing on swings*. Danish Scientific Journal. 54(1). 29-38. <http://www.danish-journal.com>
38. Antonov A. A. (2021). *Experimental refutations of the STR version contained in physics textbooks and confirmations of the truth of its alternative version*. German International Journal of Modern Science. 22. 52-61. DOI: 10.24412/2701-8369-2021-22-52-61
39. Antonov A. A. (2021). *Experimental evidence of the incorrectness of the STR version studied in physics textbooks*. Annali d'Italia. 25(1). 32-41. <https://www.anditalia.com/>
40. Antonov A. A. (2021). *The incorrectness of the STR version presented in physics textbooks proven experimentally*. Norwegian Journal of development of the International Science. 74(1). 3-7. DOI: 10.24412/2453-9875-2021-74-53-62.
41. Antonov A. A. (2021). *Experimental refutations of the generally accepted version of the STR studied in physics textbooks*. International independent scientific journal. 34(1). 23-32. <http://www.iis-journal.com>
42. Antonov A. A. (2021). *Experimental refutations of the STR version in the physics textbooks*. Journal of science. Lyon. 26(1). 29-37.
43. <https://www.joslyon.com/>
44. Antonov A. A. (2021). *Experimental evidences for the fallacy of the STR version in physics textbooks*. Sciences of Europe (Praha, Czech Republic). 82(2). 19-28. DOI: 10.24412/3162-2364-2021-82-2-19-28
45. Antonov A. A. (2021). *The version of STR stated in physics textbooks is incorrect, as it denies the existence of radio engineering*. 82nd International Scientific Conference of the Eurasian Scientific Association "Scientific results in theory and practice". Moscow. ESA. 11-15. (In Russian). <https://esa-conference.ru/sborniki/?y=2021>
46. Antonov A. A. (2022). *The version of STR presented in physics textbooks is incorrect, since it follows from it that radio engineering should not exist*. European Journal of Applied Sciences. Services for Science and Education. UK. 10(1). 440-445. DOI: doi.org/10.14738/aivp.101.2022
47. Antonov A. A. (2022). *The existence of radio engineering refutes the physics textbooks' version of STR*. The scientific heritage. (Budapest, Hungary). 83(1). 19-22. DOI: 10.24412/9215-0365-2022-83-1-19-22
48. Antonov A.A. (2022). *The fundamental Ohm's law in radio engineering as interpreted by Steinmetz, which proves the physical reality on imaginary capacitive and inductive reactances, refuted the version of the STR presented in physics textbooks even before its creation*. German International Journal of Modern Science. 26. 50-53. DOI: 10.24412/2701-8369-2022-26-50-63
49. Antonov A.A. (2022). *The version of STR stated in physics textbooks is refuted by the existence of radio engineering*. Danish Scientific Journal. 56. 56-59. <http://www.danish-journal.com>
50. Antonov A.A. (2022). *The version of STR presented in physics textbooks is incorrect because it denies the possibility of the existence of Ohm's law as interpreted by Steinmetz and, consequently, the existence of radio engineering*. Annali d'Italia. 28(1), 43-47. <https://www.anditalia.com/>
51. Antonov A.A. (2022). *The version of STR stated in physics textbooks is refuted by the existence of radio engineering*. Norwegian Journal of development of the International Science. 78(1). 63-67. DOI: 10.24412/3453-9875-2022-78-63-66.

52. Antonov A.A. (2022). *If the physics textbook version of STR were true, then Ohm's law should not exist in nature, and therefore all radio engineering would not exist.* International independent scientific journal. 36. 16-19. <http://www.iis-journal.com>
53. Antonov A.A. (2022). *If the version of STR in physics textbooks were true, then there would be no radar, no television, no radio navigation, no telecommunication and many other things.* Journal of science. Lyon. 28. 76-79. <https://www.joslyon.com/>
54. Antonov A.A. (2022). *The version of STR set out in physics textbooks is incorrect because it states that Ohm's law as interpreted by Steinmetz does not really exist, and therefore radio engineering does not exist either.* Sciences of Europe (Praha, Czech Republic). 87(1). 54-57. DOI: 10.24412/3162-2364-2022-1-54-57
55. Antonov A.A. (2022). *The version of STR set out in physics textbooks is incorrect because it states that Ohm's law as interpreted by Steinmetz does not really exist, and therefore radio engineering does not exist either.* Sciences of Europe (Praha, Czech Republic). 87(1). 54-57.
56. Antonov A.A. (2022). *Why the physics textbooks teach an incorrect version of the special theory of relativity which denies the existence of radio- and electrical engineering.* III international scientific conference "Challenges and problems of modern science." London. Great Britain. 78-86. DOI: <https://doi.org/10.528/zenodo.7486814>
57. Steinmetz C. P. (2010). *Theory and Calculation of Electric Circuit.* Nabu Press. Charlstone.
58. Cherenkov P.A. (1959). *Radiation of particles with superluminal speed and some applications of this radiation in experimental physics.* Advances in Physical Sciences. 68(3). 377-386. (In Russian). DOI: <https://doi.org/10.3367/UFNr.0068.195907b.0377>
59. Adam T., Agafonova N., Aleksandrov A. et al. (2012). *Measurement of the neutrino velocity with the OPERA detector in the CNGS beam.* arxiv:1109.4897v4 [hep-ex].
60. Antonov A. A. (2008). *Physical Reality of Resonance on Complex Frequencies.* European Journal of Scientific Research. 21(4). 627-641.
61. Antonov A. A. (2009). *Resonance on Real and Complex Frequencies.* European Journal of Scientific Research. 28(2). 193-204.
62. Antonov A. A. (2010). *New Interpretation of Resonance.* International Journal of Pure and Applied Sciences and Technology. 1(2). 1-12. http://doi.org/10.17686/sced_rusnauka_2010-888
63. Antonov A. A. (2010). *Oscillation processes as a tool of physics cognition.* American Journal of Scientific and Industrial Research. 1(2). 342-349.
64. doi:10.5251/ajsir.2010.1.2.342.349
65. Antonov A. A. (2010). *Solution of algebraic quadratic equations taking into account transitional processes in oscillation systems.* General Mathematics Notes. 1(9). 11-16. http://doi.org/10.17686/sced_rusnauka_2010-887
66. Antonov A. A. (2013). *Physical Reality of Complex Numbers.* International Journal of Management, IT and Engineering. 3(4). 219-230. http://doi.org/10.17686/sced_rusnauka_2013-898
67. Antonov A. A. (2015). *Physical reality of complex numbers is proved by research of resonance.* General Mathematics Notes. 31(2). 34-53.
68. http://www.emis.de/journals/GMN/yahoo_site_admin/assets/docs/4GMN-9212-V31N2.1293701.pdf
69. Antonov A.A. (2015). *Principle of physical reality of imaginary and complex numbers in the modern cosmology: the nature of dark matter and dark energy.* Journal of the Russian physico-chemical Society. 87(1). 328-355. http://doi.org/10.17686/sced_rusnauka_2015-1119
70. Antonov A. A. (2016). *Physical Reality and Nature of Imaginary, Complex and Hypercomplex Numbers.* General Mathematics Notes. 35(2). 40-63. http://www.geman.in/yahoo_site_admin/assets/docs/4_GMN-10932-V35N2.31895146.pdf
71. Antonov A.A. (2017). *The physical reality and essence of imaginary numbers.* Norwegian Journal of development of the International Science. 6. 50-63. <http://www.njd-iscience.com>
72. Antonov A. A. (2024). *Physical reality of imaginary numbers and their physical essence.* Danish Scientific Journal. 80. 25-35. <https://doi.org/10.5281/zenodo.10594282>
73. Antonov A. A. (2024). *Proof of physical reality of imaginary numbers and explanation of their physical essence.* German International Journal of Modern Science. 72. 17-27.
74. Anonov A. A. (2024). *Physical reality of imaginary numbers and their physical essence.* Sciences of Europe. (Praha, Czech Republic). 133(1). 79-90. DOI: 10.5281/zenodo.10575590
75. Antonov A. A. (2024). *Physical reality of imaginary numbers and their physical essence.* The scientific heritage. (Budapest, Hungary). 129. 43-53. DOI: 10.5281/zenodo.10558263

76. Antonov A. A. (2024). Proving Physical Reality and Explaining the Physical Essence of Imaginary Numbers. *European Journal of Applied Sciences. Services for Science and Education. UK.* 12(2). 362-381. DOI:10.14738/aivp.122.16273
77. Antonov A. A. (2024). Proving Physical Reality and Explaining Physical Essence of Imaginary Numbers. *Journal of science. Lyon.* 50. 25-35. <https://doi.org/10.5281/zenodo.10609816>
78. Antonov A. A. (2024). Physical reality of complex numbers and their physical essence. *International independent scientific journal.* 58. 3-13. <https://doi.org/10.5281/zenodo.10491923>
79. Antonov A. A. (2024). Proof of physical reality of imaginary numbers and explanation of their physical essence. *Annali d'Italia.* 51, 25-35. DOI: 10.5281/zenodo.10573831
80. Antonov A. A. (2011). Structure of the Multiverse. *British Journal of Science.* 2(2). 51-60. http://doi.org/10.17686/sced_rusnauka_2011892
81. Antonov A. A. (2012). Multiverse. Time Travels. *International Journal of Pure and Applied Sciences and Technology.* 12(2). 43-56. http://doi.org/10.17686/sced_rusnauka_2012-896
82. Antonov A.A. (2012). Discovery of the real Multiverse. *Encyclopaedia of Russian thought, Papers to the Russian Physical Society.* 16(3). 3-20. (In Russian). http://doi.org/10.17686/sced_rusnauka_2012-1115
83. Antonov A.A. (2013). Cognition of the Multiverse as a factor in accelerating the development of human civilisation. *Journal of Russian physical thought.* 1-12, 6-77. http://doi.org/10.17686/sced_rusnauka_2011-1117. (In Russian)
84. Antonov A. A. (2015). Hidden Multiverse. *International Journal of Advanced Research in Physical Science.* 2(1). 25-32. http://doi.org/10.17686/sced_rusnauka_2015-903.
85. Antonov A.A. (2015). The astrophysical phenomenon of dark matter and dark energy proves the existence of the hidden Multiverse. *American Journal of Modern Physics.* 4(4). 180-188. doi: 10.11648/j.jamp.20150404.14
86. Antonov A. A. (2015). Why dark matter and dark energy are invisible? *Optics.* 4(6), 43-47. doi: 10.11648/j.optics.20150406.12
87. Antonov A. A. (2016). Stargates of the hidden Multiverse. *Philosophy and cosmology.* 6. 11-27. (In Russian) <http://ispcjournal.org/journals/2016-16/Antonov16.pdf>
88. Antonov A. A. (2016). What Physical World do We Live in? *Journal of Modern Physics.* 7(14). 1933-1943. <http://dx.doi.org/10.4236/jmp.2016.714170>
89. Nicolson I. (2007). *Dark Side of the Universe: Dark Matter, Dark Energy, and the Fate of the Cosmos.* Johns Hopkins University Press. Baltimore.
90. Ruiz-Lapuente, P. Ed. (2010). *Dark Energy: Observational and Theoretical Approaches.* Cambridge university press. Cambridge. UK.
91. Amendola L., Shinji T.S. (2010). *Dark Energy: Theory and Observations.* Cambridge university press. Cambridge. UK.
92. Bertone G. Ed. (2013). *Particle Dark Matter: Observations, Models and Searches.* Cambridge university press. Cambridge. UK.
93. Sanders R.H. (2014). *The dark matter problem: a historical perspective.* Cambridge university press. Cambridge. UK.
94. Tyson N. de Grasse. (2017). *Astrophysics for People in a Hurry.* W. W. Norton & Company. NY. London.
95. Antonov A.A. (2022). Dark Matter and Dark Energy, Which are Inexplicable in the Micro-cosm, are Mutually Invisible Universes and Anti-universes of the Hidden Multiverse. *European Journal of Applied Sciences, Services for Science and Education. UK.* 13(06). 84-107. DOI:10.14738/aivp.1306.19658.
96. Antonov A. A. 2025. Dark matter and dark energy are mutually invisible universes and anti-universes of the hidden Multiverse. *German International Journal of Modern Science.* 113. 27- 42. DOI: 10.5281/zenodo.17286973
97. Antonov A. A. 2025. Dark matter and dark energy are invisible universes and anti-universes of the hidden Multiverse. *Journal of science. Lyon.* 71. 38-52. <https://doi.org/10.5281/zenodo.17533496>
98. Antonov A. A. 2025. Dark matter and dark energy are mutually invisible universes and anti-universes of the hidden Multiverse. *Annali d'Italia.* 72. 28-42. DOI: 10.5281/zenodo.17463768
99. Antonov A. A. 2025. Dark matter and dark energy, which are inexplicable in the micro-cosm, are universes and anti-universes of the hidden Multiverse. XVIII International Scientific and Practical Conference "Theoretical and practical perspectives of modern science". 28-29.10.2025, Stockholm. Sweden. 69-86. DOI <https://doi.org/10.5281/zenodo.17513357>

100. Hinshaw G., Larson D., Komatsu E., et al. (2013) *Nine Year Wilkinson Anisotropy Probe (WMAP) Observations: Cosmological Parameter Results*. arXiv:1213.5226 [astro-ph/CO].
101. Adam R., Ade P.A.R., Aghanim N., et al. (2015). *Planck 2015 Results. 1. Overview of Products and Scientific Results*. arXiv:1502.01582v2 [astro-ph.CO].
102. Korn G., Korn T. (1968). *Handbook of mathematics for scientists and engineers*. Nauka Publishing House. Moscow. (In Russian)
103. *Encyclopaedia of Mathematics*. (1979). Edited by Vinogradov I. M. Vol. 2. Publishing house "Soviet Encyclopaedia". Moscow. (In Russian)
104. Kantor I.L. , Solodovnikov A.S. *Hypercomplex Numbers. An Elementary Introduction to Algebras* Springer. NY. 2011.
105. Chernobrov V. (2000). *Encyclopaedia of mysterious places of the Earth*. Veche Publishing House. Moscow. (In Russian)
106. Chernobrov V. (2004). *Encyclopaedia of mysterious places of Russia*. Veche Publishing House. Moscow. (In Russian)
107. Chernobrov V. (2007). *Encyclopaedia of mysterious places of the Earth and space*. Veche Publishing House. Moscow. (In Russian)
108. Chernobrov V. (2009). *Encyclopaedia of mysterious places of Moskva and Moscow region*. Helios ARV. Moscow. (In Russian)
109. Antonov A. A. (2020). *How to See Invisible Universes*. *Journal of Modern Physics*. 11(05), 593-607. DOI: 10.4236/jmp.2020.115039
110. Antonov A. A. (2020). *Universes Being Invisible on Earth outside the Portals Are Visible in Portals*. *Natural Science*. 12(8). 569-587.
111. <https://doi.org/10.4236/ns.2020.128044>
112. Antonov A. A. (2020). *Invisible universes can be seen in anomalous zones*. *Danish Scientific Journal*. 43(1). 9-24. <http://www.danish-journal.com>
113. Antonov A. A. (2024). *Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals*. *German International Journal of Modern Science*. 92. 67-80. DOI: 10.5281/zenodo.14181333
114. Antonov A. A. (2024). *Experimental evidence for the existence of other mutually invisible universes neighboring our visible universe*. *European Journal of Applied Sciences. Services for Science and Education*. UK. 12(5). 385-408. DOI:10.14738/aivp.125.17785.
115. Antonov A. A. (2024). *Experimentally proved and actually physically existing imaginary numbers as a tool to explain the principle of relativism in STR*. *Norwegian Journal of development of the International Science*. 144. 69-82. <https://doi.org/10.5281/zenodo.14169132>
116. Antonov A. A. (2020). *Can invisible universes be seen?* *International independent scientific journal*. 21(2). 51-60. <http://www.iis-journal.com>
117. Antonov A. A. (2020), *How to discover invisible universes*. *Norwegian Journal of development of the International Science*. 42(1). 36-48. <http://www.njd-iscience.com>
118. Antonov A. A. 2024. *Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals*. *Sciences of Europe (Praha, Czech Republic)*. 153. 93-106. DOI: 10.5281/zenodo.14227583
119. Antonov A. A. (2021). *Invisible universes can be seen in anomalous zones*. *International independent scientific journal*. 23(1). 28-44.
120. Antonov A. A. (2024). *Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals*. *Annali d'Italia*. 61. 43-57. DOI: 10.5281/zenodo.14230824
121. Antonov A. A. (2024). *Proof of the existence of other mutually invisible universes neighboring to our visible universe*. *Danish Scientific Journal*. 90. 111-125. <https://doi.org/10.5281/zenodo.14236925>
122. Antonov A. A. (2024). *Discovery of other constellations in portals that are invisible outside the portals is experimental proof of the existence of mutually invisible universes adjacent to our visible universe*. *Polish journal of Science*. 80. 24-38. DOI: 10.5281/zenodo.14176574
123. Antonov A. A. (2024). *It is possible to prove the existence of other mutually invisible universes adjacent to our visible universe by astronomical observations in the portals of constellations that are invisible outside the portals*. *Slovak international scientific journal (Bra-tislava, Slovakia)*. 89. 51-65. DOI: 10.5281/zenodo.14167109

124. Antonov A. A. (2024). *Experimentally proved and actually psychically existing imaginary numbers as a tool to explain the principle of relativism in STR. The scientific heritage (Bu-dapest, Hungary).* 149. 50-63. DOI: 10.5281/zenodo.14214530
125. Antonov A. A. (2024). *Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. International independent scientific journal.* 67. 29-42. <https://doi.org/10.5281/zenodo.14055388>
126. Antonov A. A. (2024). *Besides our visible universe, there are other invisible universes. Journal of Science. Lyon.* 59. 13-26. <https://doi.org/10.5281/zenodo.14049575>
127. Antonov A. A. (2024). *Discovery of constellations in portals that are invisible outside the portals proves the existence of mutually invisible universes adjacent to our visible universe. Sciences of Europe (Praha, Czech Republic).* 94. 34- 48. DOI: 10.5281/zenodo.14167218
128. Antonov A. A. 2024. *Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations in-visible outside the portals. Sciences of Europe (Praha, Czech Republic).* 153. 93-106. DOI: 10.5281/zenodo.14227583
129. Antonov A. A. (2024). *Proof of the existence of other mutually invisible universes neighboring to our visible universe. Danish Scientific Journal .* 90. 111-125. <https://doi.org/10.5281/zenodo.14236925>
130. Antonov A. A. (2024). *It is possible to prove the existence of other mutually invisible universes adjacent to our visible universe by astronomical observations in the portals of constellations that are invisible outside the portals. Slovak international scientific journal (Bratislava, Slovakia).* 89. 51-65.
131. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travel for people on Earth is physically possible and technically feasible. European Journal of Applied Sciences. Services for Science and Education. UK.* 14(01). 723-744. <https://doi.org/10.14738/aivp.1401.19957>
132. Antonov A. A. (2026). *Time travels on Earth is already available to peoples. VI international scientific conference "Dialogue of Times: Past, Present, Future" Brussels. Belgium.* DOI <https://doi.org/10.5281/zenodo.19823915>
133. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travels is now available to people on Earth. Danish Scientific Journal my article.* 107. 74-88. DOI <https://doi.org/10.5281/zenodo.19823915>
134. Antonov A. A. (2026). *Time travel for people on Earth physically is possible and now already technically feasible. XXIII International Scientific Conference "Modern Science: Theoretical and Practical View". Madrid. Spain.* 31.03-01.04.2026. DOI <https://doi.org/10.5281/zenodo.19442313>
135. Antonov A. A. (2026). *Time travel on Earth is available for use. Annali d'Italia.* 76. 52- 65. DOI: 10.5281/zenodo.18803259.
136. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travels is now available to people on Earth. XIX international scientific conference. "Questions. Hypotheses. Answers: science XXI century". Toronto. Canada.* 17-18.03.2026 DOI <https://doi.org/10.5281/zenodo.19188055>.
137. Antonov A. A. (2026). *How to call yourself to yesterday? Norwegian Journal of development of the International Science.* 172. 23-36. <https://doi.org/10.5281/zenodo.18268393>
138. Antonov A. A. (2026). *Time travels according to the corrected version of STR is physically feasible" in the XXIII international scientific conference "The modern vector of the development of science". Philadelphia. USA.* 29-30.01.2026. DOI <https://doi.org/10.5281/zenodo.18472454>
139. Antonov A. A. (2026). *Time travels is already technically feasible for people on Earth" in the VI international scientific conference "Innovative scientific forum". Helsinki. Finland.* 02-03.04.2026. DOI <https://doi.org/10.5281/zenodo.19460273>
140. Antonov A. A. (2026). *Time travel on Earth is physically and technically feasible. Journal of Science. Lyon.* 75. 28-41. <https://doi.org/10.5281/zenodo.18888329>
141. Antonov A. A. (2026). *Time travels according to the corrected version of the special relativity theory. XIX International Scientific and Practical Conference "Theoretical and practical perspectives of modern science", 13-14.01.2026., Stockholm. Sweden.* DOI <https://doi.org/10.5281/zenodo.18303431>
142. Antonov A. A. (2025). *The physical ability to bring a person who has died, for example as a result of an accident or a crime, back to life. Polish journal of Science.* 89(1). 36-39. DOI: 10.5281/zenodo.16917782

143. Antonov A. A. (2025). *The use of the laws of physics allows a person who has died, for example, as a result of an accident or crime, to be brought back to life.* *European Journal of Applied Sciences. Services for Science and Education. UK.* 13(04). 174-179. DOI:10.14738/aivp.1304.19179.
144. Antonov A. A. (2025). *By using the laws of physics, it is possible to bring back to life a person who has died, for example, as a result of an accident or crime.* *The scientific heritage.* 166. 65-68. DOI: 10.5281/zenodo.1676353
145. Antonov A. A. (2025). *It is physically possible to bring back to life a person who has died, for example, as a result of an accident or crime, using time travels.* *German International Journal of Modern Science.* 109. 24-27. DOI: 10.5281/zenodo.16752567
146. Antonov A. A. (2025). *The laws of physics allow a person who has died, for example, as a result of an accident or crime, to be brought back to life.* *Danish Scientific Journal.* 98. 67-71. <https://doi.org/10.5281/zenodo.16615081>
147. Antonov A. A. (2025). *It is physically possible to bring back to life a person who has died as a result of an accident or crime by using time travels.* *Annali d'Italia.* 69. 46-49. DOI: 10.5281/zenodo.16419980
148. Antonov A. A. (2025). *Possibility in accordance with the laws of physics, of bringing back to life people who have died as a result of accident and other causes by time travels using time zones on Earth.* XVI International scientific conference. Beijing. China. "Science in modern society"22-23.07.2025. DOI <https://doi.org/10.5281/zenodo.16562393>
149. Antonov A. A. (2025). *How the laws of physics can be used to bring back to life a person who has died as a result of an accident or crime.* *Norwegian Journal of development of the International Science.* 160. 69-72. <https://doi.org/10.5281/zenodo.15879906>
150. Antonov A. A. (2025). *A person who has died in an accident or crime, for example, can be brought back to life through the use of time travels.* *International independent scientific journal.*76. 17-20. <https://doi.org/10.5281/zenodo.16778574>
151. Antonov A. A. (2025). *The laws of physics allow a dead person to be brought back to life.* *Journal of Science. Lyon.* 68.15-18. <https://doi.org/10.5281/zenodo.16758455>
152. Antonov A. A. (2025). *The laws of physics allow by time travelling with using time zones on Earth to bring back to life people who died as a result of accidents, in war and for other reasons.* XVII International scientific conference "Theoretical and practical perspectives of modern science". Stockholm. Sweden. 12-13.08.2025. DOI <https://doi.org/10.5281/zenodo.16892861>

Technical sciences

PERSPECTIVES FOR THE PRODUCTION AND USE OF MOTOR BIOFUELS IN UKRAINE AND IN THE EU

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Abstract

Decarbonisation of the transport sector is a key element of the EU's pathway to climate neutrality by 2050, and boosting the production and use of motor biofuels is central to this effort. This article aims to determine the most promising types of motor biofuels to be produced and consumed in Ukraine and the EU. First, the potential of biomass available for biofuel and energy production in the EU and Ukraine is considered, and the factors driving its growth in the medium and long term are indicated. In the EU, the current annual biomass supply exceeds 10 EJ and may reach 15-20 EJ/y by 2050, with intermediate and cover crops increasingly regarded as a major contributor to the future agricultural biomass potential. In Ukraine, the economic potential of biomass is assessed at nearly 26 Mtoe/y and may rise to about 44 Mtoe/y by 2050. The demand for motor biofuels in Ukraine and their export potential are then analysed against the binding EU targets set by RED III and the ReFuelEU Aviation Regulation, which together generate a significant and rising demand for sustainable and advanced biofuels. To determine feasible project types, a techno-economic assessment of biofuel production under Ukraine's conditions has been performed, supported by mass-balance calculations for the main production pathways. The obtained results show that, under the current circumstances, some projects are much more feasible than others, with the simple payback period ranging from 3-4 to 6-9 years. A medium-term scenario for the production of motor biofuels in Ukraine until 2035 is elaborated, envisaging a gradual shift from first-generation biofuels towards advanced biofuels. Based on an analysis of relevant international studies, the available biomass potential in Ukraine, and the results of the performed feasibility study, the most prospective types of motor biofuels for production and consumption in Ukraine have been determined. To support further development of this sector in Ukraine, it is necessary to introduce additional incentives at the state level. Analysis of the current situation and the binding targets for the EU shows that an important direction is developing the production of advanced biofuels, including sustainable aviation biofuels from lignocellulosic biomass and waste.

Keywords: *bioenergy, biomass, biofuels, motor biofuels, advanced biofuels, biodiesel, bioethanol, feasibility study*

Introduction

Decarbonisation of the economy and energy is a global challenge of the present time caused by the necessity to mitigate greenhouse gas (GHG) emissions and hold down the process of climate change. The European Green Deal is the main current strategy of the EU focused on achieving climate neutrality by 2050. The present contribution of the transport sector to the EU's total GHG emissions is about 25%, with a rising tendency. To reach the 2050 goal of carbon neutrality in Europe, a considerable, up to 90% reduction of GHG emissions in transport should be attained. The emphasis is on road transport, the aviation and maritime sectors. Boosting the production and use of biofuels in these sectors is an important part of the ambitious transport strategy within the European Green Deal [1-3]. For example, it is planned to reduce emissions from cars by 55% and emissions from vans by 50% by 2030, as well as provide zero emissions from new cars by 2035. To promote the consumption of sustainable aviation fuels (SAF), the minimum share of SAF required for blending with kerosene by European suppliers of aviation fuel has been increased. To give an incentive for using renewable and low-carbon marine fuels, a goal to gradually reduce the annual average GHG intensity of energy used by ships has been set. Regulation (EU) 2023/2405 (ReFuelEU Aviation Regulation), adopted in 2023, set binding EU targets for the consumption of SAF, resulting in a significant increase in demand for these fuels in the EU. This Regulation is part of the "Fit for 55" legislative package, which aims to achieve a reduction in EU GHG emissions of at least 55% by 2030.

The main provisions of the EU Renewable Energy Directive 2018 (RED II) regarding the transport sector were generally in line with the European Green Deal transport policy. The main mandatory goal

was to reach at least 14% of renewable energy in the final energy consumption in transport. At that, the Directive promoted the production of advanced biofuels, that is, biofuels obtained from lignocellulosic material, non-food cellulosic material, biomass fraction of municipal and industrial waste and other types of feedstocks listed in Part A of Annex IX of RED II [4, 5]. The new version of the Renewable Energy Directive adopted in 2023 (RED III) allows the Member States to choose between the transport target expressed as a GHG intensity reduction (at least 14.5% by 2030) and the share of renewable energy consumption in the transport sector (at least 29% by 2030). RED III pays special attention to biofuels for the aviation sector. In accordance with Part A of Annex IX, biofuels produced from intermediate crops and crops cultivated on severely degraded land (except for food and feed crops) for aviation are considered advanced.

Being a member of the Energy Community on its way to the European Union, Ukraine is gradually implementing the main provisions of the Renewable Energy Directives. One of them applies to the introduction of renewable energy, including biofuels, in the transport sector. One of them applies to the introduction of renewable energy, including biofuels, in the transport sector. The National Transport Strategy of Ukraine until 2030 establishes a target to achieve 50% consumption of biofuels and electricity (renewable and traditional) in the total energy consumption in transport. According to Ukraine's National Renewable Energy Action Plan until 2030, the share of energy from renewable sources in the gross final energy consumption of the transport sector will be at least 17% by 2030, which is equivalent to 830 ktoe. The consumption of liquid biofuels (bioethanol, biodiesel) will account for 420 ktoe, including bioethanol from food and feed crops – 398 ktoe, advanced bioethanol and biodiesel from waste and residues – 10 ktoe and 12 ktoe, respectively. Additionally, the consumption of biomethane from waste and residues (II generation) will be 0.5 ktoe. Some other estimated shares of renewable energy sources (RES) in the transport sector, as specified in the National Energy and Climate Plan of Ukraine for 2025-2030 (NECP), are as follows for consumption by 2030: bioethanol and biodiesel from food and feed crops – 190 ktoe and 70 ktoe, respectively; advanced bioethanol and biodiesel from waste and residues – 48 ktoe and 17 ktoe, respectively; biomethane from food and feed crops – 5 ktoe, and biomethane from waste and residues (II generation) – 1 ktoe. By 2030, the total consumption in the transport sector is 325 ktoe of liquid biofuel (bioethanol, biodiesel) and 6 ktoe of biomethane. NECP fixes the target to have 14% of renewable energy in transport in 2030.

Russia's invasion of Ukraine in 2022 caused the energy crisis and a rapid increase in fossil fuel prices in Europe. At the same time, restrictions and difficulties on the ability to transport agricultural commodities abroad, along with global market trends, led to low prices for grain and oilseeds in Ukraine. Farmers also have a lack of opportunities for proper storage of agricultural products. Thus, conditions have been created in Ukraine for the introduction of processing grain and oilseeds into biofuels to provide the energy transition for a green economy. The agricultural sector is interested in the production of biofuels, which will allow the processing of unsold and surplus products, including those of poor quality, to obtain biofuels to replace traditional light petroleum products. Besides, it is possible to obtain advanced biofuels from cheap waste streams of biomass, which requires the application of more sophisticated technologies than for the production of first-generation biofuels. The development of biofuel production will also contribute to the fulfilment of Ukraine's obligations to reduce GHG emissions. In addition to domestic use, the produced biofuels can be exported to the EU.

The purpose of the article is to determine the most promising types of motor biofuels to be produced and used in Ukraine and the EU. Research methods include studying literature data, analysing statistical data and performing calculations.

1. Bioenergy potential in the EU and in Ukraine

The current annual biomass supply in the EU is more than 10 EJ, including about 7 EJ of woody biomass, 2 EJ of agricultural biomass and 1.5 EJ of waste. The existing estimates of biomass supply for 2050 differ a lot, the average range being about 15-20 EJ/y. The share of agricultural biomass in the future biomass supply is assessed at 30-50% [22, 23]. Among the agricultural biomass types, cover crops are expected to play a notable role in the future biomass supply, contributing 14-24% of the total biomass potential by 2030 and 15-26% by 2050 (Table 1) [24]. Recently, intermediate and cover crops have been considered one of the main factors for increasing the bioenergy potential in the EU [26]. From the biomass demand side, one can say that it can be fully covered by the available bioenergy potential. The current biomass demand for energy in the EU is estimated at over 7 EJ/y, while by 2050, it may increase to 9-18 EJ/y.

Table 1. Biomass potential for energy in the EU [24].

Biomass type	Biomass potential for energy, Mt		Potential of feedstock for SAF production, Mt
	2030	2050	2030
Waste oil and fats	5.3	9.9	2.4
Organic fraction in municipal solid waste	44-80	33-61	21.2
Agricultural residues	45-65	65-71	87.7
Cover crops	36-108	42-127	
Primary forest residues	41-68	45-75	5.1
Secondary forest residues	89-126	93-139	

Biomass feedstock available for SAF production occupies a special place in the EU's bioenergy potential, as it has an effect on meeting the ReFuelEU Aviation binding targets. Regulation (EU) 2023/2405 requires that the minimum share of SAF in the aviation fuel at the EU's airports must be 2% in 2025, rising to 70% in 2050. SAF include advanced biofuels and other biofuels, produced from waste and residues, as well as synthetic aviation fuels obtained from renewable hydrogen, and recycled carbon aviation fuels. These targets envisage a considerable increase in the production of SAF, including sustainable biofuels. Analysis of the available feedstock structure (see Table 1) shows that the aviation biofuels should be obtained mostly from lignocellulosic biomass. Examples of such biofuels are alcohol-to-jet synthetic paraffinic kerosene (ATJ-SPK) and Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene (FT-SPK) [25].

Ukraine, in its bioenergy development, tries to follow the main European tendencies. The country has a big potential of biomass available for energy production. This is probably one of the most important preconditions for the development of the bioenergy sector and replacement of expensive fossil fuels [6, 7]. The economic potential of biomass is assessed at nearly 26 Mtoe/y with the biggest contribution from agricultural residues (42% of the total) and energy crops (21%) [8, 9]. By 2050, the biomass potential may increase to about 44 Mtoe/y due to several factors, the main of which are:

- possible increase in the yield of main agricultural crops;
- possible expansion of the area under energy crops;
- development of sustainable growing intermediate/cover crops as feedstock for the production of biogas/biomethane and motor biofuels.

Analysis and comparison of European and Ukrainian statistical data on agriculture shows that Ukraine still has room for increasing the yield of some cereal crops (for example, wheat and maize) by at least 1.2-1.25 times. Besides, Ukraine has quite a big area of permanently unused agricultural land (about 3 million hectares) that can be partly utilised for growing energy crops such as willow, poplar, miscanthus, camelina, and maize (silage). Biomass of the energy crops can be used as feedstock for the sustainable production of solid, liquid and gaseous biofuels. A new promising direction of bioenergy development in Ukraine is growing intermediate/cover crops to obtain biomass for biogas/biomethane production. Bioenergy experts are now actively studying this issue. It should be noted that another important research area attracting increasingly more attention in the country is the production of synthetic renewable methane [10].

Due to some obstacles, the current production of liquid biofuels in Ukraine is very low, being represented practically only by first-generation bioethanol. In 2020, the gross final consumption of energy from RES in the transport sector amounted to 95 ktoe (148 ktoe when accounting for multipliers according to Directive 2009/28/EC), of which 51.1 kt were bioethanol and ethyl tert-butyl ether produced from bioethanol.

The mandatory requirement to add at least 5% bioethanol to gasoline (with an octane number less than 98) in Ukraine came into effect on May 1, 2025. The fines and penalties for non-compliance by fuel sellers were initially deferred (by Law of Ukraine No. 4505-IX) until January 1, 2026, and subsequently deferred again until July 1, 2026, to allow the market to adapt and ensure a consistent supply. However, under amendments to the Law of Ukraine "On Alternative Fuels" adopted by the Ukrainian Parliament on February 10, 2026 (entering into force in March 2026), the minimum requirement is raised, from July 1, 2026, to more than 7% bioethanol by volume in gasoline below 98 octane number, provided that the oxygen content does not exceed 3.7% by mass.

Analysis of the structure and volume of the current and prospective biomass potential in the country indicates good prerequisites for the production of different motor biofuels, including advanced ones. Now, it is a question of biodiesel and bioethanol for road transport; however, in the post-war period, it is

necessary to study the matter of biofuels for aviation (SAF) and for waterborne transport (biodiesel, Fischer-Tropsch diesel, bio-oil of biomass fast pyrolysis) [11].

Analysis of international theoretical and practical studies indicates the following leading-edge technologies for further research and development:

- Production of advanced bioethanol and Fischer-Tropsch diesel from lignocellulosic feedstock.
- Production of hydrotreated vegetable oil (renewable diesel fuel).
- Production of sustainable aviation fuels such as synthesized paraffinic kerosene (SPK) from hydroprocessed esters and fatty acids, alcohol to jet SPK, and Fischer-Tropsch hydroprocessed SPK.

This article considers only motor biofuels for road transport, while further studies surely should cover the issues of sustainable fuels for aviation and waterborne transport.

2. Analysis of demand for motor biofuels in Ukraine and their export potential

Demand for motor biofuels in Ukraine is mainly determined by a combination of the current consumption of petrol and diesel and existing technical constraints for replacing them with bioethanol and biodiesel, respectively. The consumption of main motor fuels in Ukraine during 2017-2021 was quite stable with some small fluctuations: petrol 1.7-2.0 Mt/y, diesel fuel 5.1-5.8 Mt/y. At that, the use of liquefied propane and butane increased from 0.89 Mt in 2017 to 1.3 Mt in 2021 (Table 2). Statistical data for the period later than 2021 are not available because they are not published due to the state of martial law in the country.

Table 2. Consumption of motor fuels in Ukraine.

Fuel type	2017	2018	2019	2020	2021	2025*
Motor petrol, Mt	2.0	1.8	1.7	1.8	2.0	2.3
Gas oils (diesel fuel), Mt	5.1	5.4	5.8	5.2	5.7	3.1
Liquefied propane and butane, Mt	0.89	1.0	1.2	1.4	1.3	1.6

* Official statistics for the period after 2021 are not published due to the state of martial law. Data for 2025 are approximate, according to industry estimates based on retail sales data.

Based on data on the use of motor fuels in Ukraine in 2021, the volume of the domestic market for bioethanol can be estimated as 210 kt/y (on condition of blending 10% vol. bioethanol with petrol), and that for biodiesel is 290 kt/year (on condition of blending 5% vol. biodiesel with diesel fuel). In the case of the production of hydrotreated vegetable oil (HVO), the volume of its use in Ukraine's domestic market can be much larger, since the properties of HVO allow its use as a direct substitute for diesel fuel [12]. Besides, if there is a large number of flex-fuel vehicles in use in Ukraine, the volume of bioethanol consumption in the domestic market will also be considerably higher. The design of flex-fuel vehicles allows their running on petrol mixed with up to 50-85% bioethanol [13].

Bioethanol is used as an oxygen-containing additive to petrol and diesel or as a biologically renewable alternative to petrol. When added to petrol, it increases its octane number and saturates it with oxygen, which leads to more complete combustion and a reduction in emissions of harmful substances. From the chemical point of view, biodiesel is a mixture of fatty acid methyl ethers (FAME) of vegetable oils that contain 11% oxygen, while diesel fuel and HVO are hydrocarbons that do not contain oxygen. Due to its oxygen content, FAME has a lower calorific value, resulting in higher biofuel consumption as compared to traditional diesel fuel. Diesel fuel comprises aromatic hydrocarbons, while HVO consists only of fully saturated paraffinic hydrocarbons. The cetane number and lower calorific value of HVO are higher than those of diesel and FAME. Applications of FAME under cold weather are limited due to poorer low-temperature properties as compared to conventional diesel and HVO.

It is expected that the amount of potentially produced biofuels that exceeds Ukraine's domestic demand may be exported. First of all, this applies to advanced (second-generation) biofuels, as they are sustainable. The sustainability of biofuels that are exported can be confirmed by a relevant certification system, for example, by ISCC (International Sustainability and Carbon Certification). Such certification is obligatory for biofuels that are exported to the EU and voluntary for biofuels that are exported to countries outside the EU [14].

According to McKinsey & Company's forecast [15], the global demand for sustainable motor fuels will grow to about 220 Mt/y by 2035, with a subsequent decrease to the level of 2025 (about 170 Mt/y). By 2050, the largest increase in demand is expected for sustainable fuels from lignocellulosic feedstock (Fig. 1). At that, there will remain quite a great demand for fuel from oils of edible crops. It is predicted that in 2030, the largest importers of bioethanol will be Brazil, the USA, Japan, Canada, the United Kingdom, and importers of biodiesel will be the EU, the USA, the United Kingdom, Canada, and Peru [16]. The general situation may remain approximately the same also for some period after 2030.

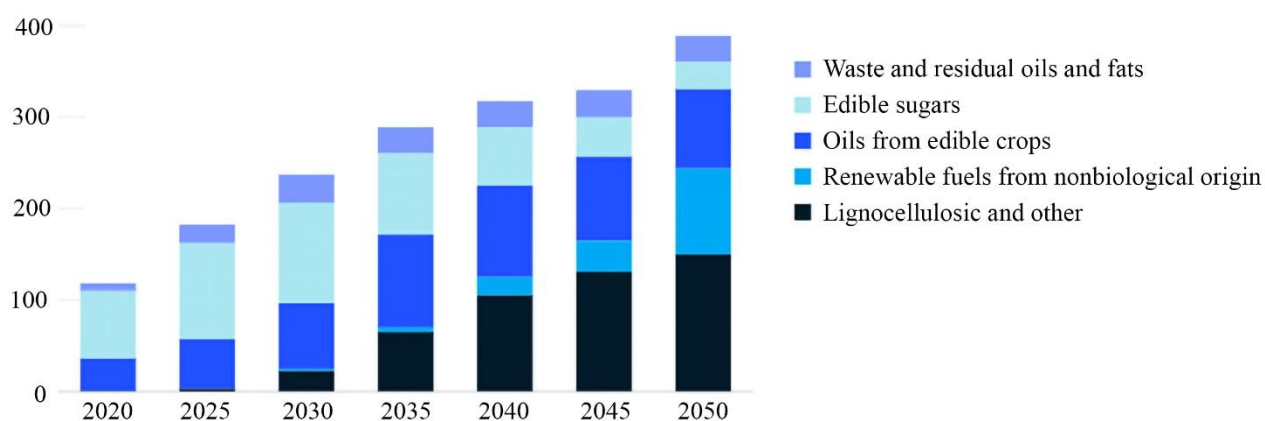


Fig. 1. Global sustainable fuel demand by feedstock type until 2050, Mt [15]

Taking into account the above data and forecasts, we have elaborated a middle-term scenario for the production of motor biofuels in Ukraine (Table 3). The scenario covers first- and second-generation biodiesel and bioethanol from different types of feedstocks, which takes into consideration the available biomass potential in Ukraine. After 2035, it seems reasonable to gradually switch from the production of biodiesel to HVO, as well as to restrict the production of first-generation bioethanol in favour of advanced biofuels. In general, the suggested basic scenario is in line with the current strategic national documents.

Table 3. Basic scenario for the production of motor biofuels in Ukraine until 2035, kt [17].

Biofuel type	2025	2030	2035
<i>Biodiesel from:</i>			
- rapeseed	56	113	226
- used cooking oil (UCO)	6	11	23
- unconditioned oils, vegetable and animal fats	0.2	0.5	0.9
- fats from livestock and poultry slaughter	6	8	11
- oil energy crops (advanced biofuel)	11	56	113
<i>Bioethanol from:</i>			
- maize grain	109	202	312
- molasses (advanced biofuel)	55	62	70
- residues of grain maize production (advanced biofuel)	31	78	234

3. Feasibility study of the production of biofuels in Ukraine

Feasibility might be a crucial aspect of biofuel production, which depends on the maturity of a certain technology, the cost of feedstock and other input materials and energy, and the possible sale price of the main product and by-products. An important feature of a biofuel production technology is its materials and energy intensity. Technologies for the production of first-generation biofuels are well established and worked out, though they may be less sustainable than advanced (second-generation) biofuels in terms of GHG emissions. Advanced biofuels are sustainable as they are obtained from waste and non-edible raw materials. However, the respective technologies are very complex, and the final product may be too expensive to be competitive with traditional motor fuels. In addition to the main product (a biofuel), there can be one or more by-products which are of interest to the market. For example, dried distillers' grains (DDG) and maize oil are by-products in the case of bioethanol production from maize grain (Table 4). When producing advanced bioethanol, the process generates energy that can be used for the production own needs. The required input energy can be obtained from the lignocellulosic feedstock residues (unreacted biomass), and the surplus energy can be sold to gain additional income.

Table 4. Mass balance for the production of motor biofuels [18].

Inputs and outputs	Bioethanol from maize grain	Advanced bioethanol from lignocellulosic feedstock	Biodiesel from vegetable oil	Biodiesel from UCO	HVO
Inputs to obtain 1 l of a biofuel:					
Feedstock, kg	2.4	3.38	0.893	0.977	0.97
Chemicals, kg	-	0.38	Methanol 0.086	Methanol 0.087	Hydrogen 0.035
Power, kWh	0.20	-	0.036	0.08	0.085
Natural gas, MJ	7	-	0.93	1.71	0.27
Outputs:					
Biofuel (1 l), kg	0.79	0.79	0.88	0.88	0.77
By-products, kg	DDG 0.72 Maize oil 0.03	Power 0.70 kWh	Glycerine 0.09	Glycerine 0.09	Fuel gas 0.03 Bio-propane 0.025 Naphtha 0.06

It should be noted that the techno-economic assessment of biofuel production in Ukraine's conditions has been performed with detailed consideration of the relevant mass balances, especially regarding the input of required chemicals. The obtained results show that some projects are more feasible than others. A simple payback period (SPP) within 6 years may be achieved when producing bioethanol from maize grain and biodiesel from UCO (Table 5). These projects have the lowest operating expenses (OPEX) of the considered options. Obtaining bioethanol from lignocellulosic feedstock (such as straw) is a complex technology, and capital expenditures are high. As a result, SPP is more than 8 years in spite of comparatively low price of the feedstock (straw). Nevertheless, as such technologies are developing and improving, one can expect a noticeable decrease in the production cost of cellulosic bioethanol even in a short-term period. A promising direction for future research and development may also be obtaining advanced bioethanol from the organic fraction of municipal solid waste [19].

Table 5. Results of the feasibility study of biofuels production in Ukraine's conditions.

Indicators	Bioethanol from maize grain	Bioethanol from straw	Biodiesel from rapeseed oil	Biodiesel from UCO	HVO from rapeseed oil
Production output, kt/y	50	50	50	20	100
Operational time, h/y	8000				
Expenses:					
Feedstock consumption, kt/y	152	214	50.7	22.2	126
Feedstock purchase price, EUR/t without VAT	182	50	1050	600	1050
Feedstock cost, mln EUR	27.7	30.4	58.4	16.38	150.5
CAPEX, mln EUR	32.3	139.3	10.8	9.3	112.0
OPEX, mln EUR/y	38.1	39.0	61.8	18.3	162.7
Biofuel production expenses, EUR/l	0.6	0.62	1.09	0.81	1.25
Depreciation charges, EUR/l	0.020	0.088	0.01	0.02	0.034
Income:					
Sale price of by-products, EUR/t without VAT	DDG 162 Maize oil 1200	Power 0.096 EUR/kWh	Crude glycerine 300	Crude glycerine 300	Bio-propane 923 Naphtha 800 Fuel gas 545
Income from sale of by-products, mln EUR/y	DDG 7.4 Maize oil 2.3	Power 4.3	Crude glycerine 1.5	Crude glycerine 0.6	Bio-propane 3.0 Naphtha 6.2 Fuel gas 2.1
Biofuel net cost, EUR/l	0.47	0.64	1.07	0.79	1.2
Biofuel sale price*, EUR/l without VAT	0.6	1.0	1.1	1.1	1.4
Economic performance indicators:					
Loan share of CAPEX, %	70				
Lending period, years	5				
Loan rate in EUR, %	6				
Internal return rate (IRR), %	23.3%	13.7%	16.1%	62.8%	17.8%
Simple payback period, years	5.41	8.3	7.2	2.6	6.8

* The price does not take into account the excise tax of 100 EUR/1000 l.

As opposed to straw and other crop residues, rapeseed oil is an expensive feedstock, which negatively affects the biodiesel production projects (SPP is about 7 years). A possible solution can be switching over to a cheaper feedstock, for example, oil energy crops. UCO is not suited for this purpose as its amount is rather limited and the collection is not well organized in Ukraine. Oil energy crops can be cultivated on

permanently unused agricultural land (about 3 mln ha in Ukraine), which is considered a sustainable approach to obtaining feedstock for biofuels. Another approach to improve feasibility could be the introduction of a state subsidy or another type of support for producers of biofuels, especially the advanced ones. Now the only incentive is a zero-excite tax for bioethanol that is used for the production of blended petrol and for bioethanol that is exported. Obviously, it is not enough for the further development of the sector.

4. Analysis of biofuel production schemes

There are different organizational schemes for the production of bioethanol and biodiesel, which affect the capital and operating costs. Bioethanol from maize grain can be obtained by the classical, modern and combined approaches. In the first case, the main product is bioethanol, and the by-products are distillers dried grains with soluble (DDGS) and maize oil. This classical scheme is implemented in the existing "old" plants in the EU and the USA, where the energy needs of the technological processes are usually covered by traditional energy carriers. The modern (bioenergy) approach also envisages bioethanol as the main product, while the by-products are biogas/biomethane from distillers' grains and organic fertilizer (digestate). The produced biogas can fully meet the energy needs of the plant, and the rest of the biogas can be sold or upgraded to biomethane. Today, this approach is considered the most up-to-date for designing a bioethanol plant. In the combined scheme, 50% of the distillers' grains is used for biogas/biomethane production, and 50% for DDGS. This approach is usually applied when reconstructing the existing production facilities. The production of bioethanol from molasses, which is a by-product of the sugar industry, can be organized based on existing sugar factories. This organizational model has several advantages, including the availability of different types of infrastructure, the opportunity to use excess steam and electricity from the existing energy system, the possibility to utilize diffusion juice to increase the bioethanol yield and others.

In the case of advanced bioethanol production, the capital costs are significantly higher compared to that of first-generation bioethanol [20]. Today, bioethanol from lignocellulosic feedstock is considered one of the most expensive types of advanced biofuels, since its prime cost can reach almost 160 EUR/MWh (about 0.93 EUR/l). The greatest impact on the cost is made by the price of feedstock, the efficiency of the applied conversion technology, as well as the approach to the production process (a separate new installation or an integrated one). For example, if the production of bioethanol from maize stalks is integrated with the existing production of biofuel from maize grain, and the lignocellulosic feedstock is free of charge, then the prime cost of advanced bioethanol can be reduced by almost three times [21].

Estimates of specific CAPEX and OPEX of bioethanol plants for different feedstocks and production models are presented in Table 6. An increase in the annual production output lowers the specific capital and operating expenses, and vice versa.

Table 6. Estimate of specific capital and operating costs for different bioethanol and biodiesel production options.

Production schemes	Typical production output, ML/y	Feedstock	Feedstock price, EUR/t	CAPEX, EUR/l	OPEX, EUR/l/y
Bioethanol (the main product) + DDGS (the by-product)	30-70	maize grain	165-183	0.40-0.50	0.61-0.65
Bioethanol (the main product) + biogas (the by-product)	30-70	maize grain	165-183	0.40-0.57	0.52-0.68
Production of bioethanol (the only product) at a sugar factory	20-35	molasses	55-57	0.32-0.35	0.30-0.33
Production of bioethanol (the main product) and biogas (the by-product) at a sugar factory	20-35	molasses	55-57	0.49-0.52	0.31-0.34
Production of advanced bioethanol (the only product) at a new separate installation	60	straw	31-42	1.9-2.1	0.91-0.95
Biodiesel (the main product) + cake and glycerine (the by-products)	30-120	rape-seed	400-550	0.28-0.30	1.1-1.5
Biodiesel (the main product) + glycerine (the by-product)	50-250	rape-seed oil	850-1150	0.19-0.21	0.9-1.2
Biodiesel (the only product)	10-25	UCO	500-700	0.37-0.45	0.7-0.9

As for obtaining biodiesel from oil feedstock, it makes sense to consider two main options: the production from rapeseed with the oil as an intermediate product, and the production from rapeseed oil as a ready feedstock. The first option includes cake and glycerine as by-products; in the second option, only glycerine is a by-product. Rapeseed oil as a feedstock is much more expensive than rapeseed; however, the capital and operating costs are lower in this case (see Table 6). Comparison with used cooking oil shows that CAPEX for biodiesel production from UCO is higher than that for rapeseed and rapeseed

oil as feedstock, while OPEX is lower. The choice of feedstock depends on its availability, price, logistics and some other factors.

Conclusion

Decarbonisation of the transport sector is an important part of global GHG emissions mitigation. The problem is that it is rather difficult to decarbonize this sector, especially freight transportation, as compared to other energy sectors such as heat and power production. One of the possible directions is switching over from traditional motor fuels to biofuels. Advanced biofuels are especially effective as their use leads to a high reduction of CO₂ emissions as compared to the consumption of petrol and diesel. Based on a complex analysis of international studies and results of the performed techno-economic assessment for Ukraine's conditions, a number of biofuels can be considered prospective for the country's transport sector. They include bioethanol from maize grain, bioethanol from lignocellulosic feedstock such as straw of cereal crops, biodiesel from used cooking oil, biodiesel from oil energy crops and hydrotreated vegetable oil. The sector of motor biofuels is still at an early stage of development in Ukraine. The recommended technologies indicate a possible way for solving some urgent environmental and energy problems, in particular, the reduction of GHG and exhaust gas emissions, utilization of waste and residues, and the saving of expensive fossil fuels. The focus is expected to be on advanced biofuels as they can solve the mentioned problems more efficiently. Ukraine has enough biomass to produce first- and second-generation biofuels for the domestic market and for export. To promote the production and consumption of motor biofuels, the improvement of the relevant Ukrainian legislation is recommended. For the EU, an important direction is the development of advanced biofuels production, including sustainable aviation biofuels. Considering the necessity to significantly increase the production of SAF, the prospective aviation biofuels for the EU may be ATJ-SPK and FT-SPK.

References

1. Chiaramonti D., Talluri G., Scarlat N., et al. The challenge of forecasting the role of biofuel in EU transport decarbonisation at 2050: A meta-analysis review of published scenarios. *Renewable and Sustainable Energy Reviews*, 2021, Vol. 139, 110715, <https://doi.org/10.1016/j.rser.2021.110715>
2. Tsakalidis A., van Balen M., Gkoumas K., et al. Catalyzing Sustainable Transport Innovation through Policy Support and Monitoring: The Case of TRIMIS and the European Green Deal. *Sustainability*, 2020, Vol. 12, No. 8, 3171, <https://doi.org/10.3390/su12083171>
3. Lundberg L., Sanchez O.C., Zetterholm J. The impact of blending mandates on biofuel consumption, production, emission reductions and fuel prices. *Energy Policy*, 2023, Vol. 183, 113835, <https://doi.org/10.1016/j.enpol.2023.113835>
4. Dusser P. The European Energy Policy for 2020–2030 RED II: what future for vegetable oil as a source of bioenergy? *OCL*. 2019, Vol. 26, 51, <https://doi.org/10.1051/ocl/2019040>
5. Panoutsou C., Germer C., Karka P., et al. Advanced biofuels to decarbonise European transport by 2030: Markets, challenges, and policies that impact their successful market uptake. *Energy Strategy Reviews*, 2021, Vol. 34, 100633, <https://doi.org/10.1016/j.esr.2021.100633>
6. Geletukha G., Zheliezna T. Prospects for Bioenergy Development in Ukraine: Roadmap until 2050. *Ecological Engineering & Environmental Technology*, 2021, Vol. 22, No 5, pp. 73-81, <https://doi.org/10.12912/27197050/139346>
7. Geletukha G., Zheliezna T., Drahnev S., et al. Analysis of actions for Ukraine to replace Russian natural gas. *Ecological Engineering & Environmental Technology*, 2022, Vol. 23, No 4, pp. 1-9, <https://doi.org/10.12912/27197050/149458>
8. Tryboi O., Zheliezna T., Drahnev S. Agricultural biomass feedstock for biofuels production in Ukraine. *Technium*, 2023, Vol. 14, pp. 94-99, <https://doi.org/10.47577/technium.v14i.9686>
9. Zheliezna T., Drahnev S. Feasibility study of growing energy crops in Ukraine. *Journal of Science. Lyon*, 2024, No 50, pp. 46-51, <https://doi.org/10.5281/zenodo.10610261>
10. Klimenko V.N., Suprun T.T. Analysis of synthetic renewable methane production technologies for implementation in Ukraine. *Eurasian phys. tech. j.*, 2023. Vol. 20, No. 2, pp. 41-45, <https://doi.org/10.31489/2023No2/41-45>
11. Zheliezna T., Drahnev S. Comparative analysis of biofuels and other alternative fuels for introduction in aviation and waterborne transport of Ukraine. *Journal of Science. Lyon*, 2022, No 37, p. 37-42, <https://doi.org/10.5281/zenodo.7409774>
12. Soo-Young N. Application of hydrotreated vegetable oil from triglyceride based biomass to CI engines – a review. *Fuel*, 2014, V. 115, pp. 88-96, <https://doi.org/10.1016/j.fuel.2013.07.001>

13. Delavarrafiee M., Frey H.C. Real-world fuel use and gaseous emission rates for flex fuel vehicles operated on E85 versus gasoline. *Journal of the Air & Waste Management Association*, 2018, V. 68, No 3, pp. 235-254, <https://doi.org/10.1080/10962247.2017.1405097>
14. ISCC. <https://www.iscc-system.org/markets/sustainable-road-transport-fuels/>
15. Lash N., Melgin T., Mucha-Geppert A., et al. Charting the global energy landscape to 2050: Sustainable fuels, 2022. Available at: <https://www.mckinsey.com/industries/oil-and-gas/our-insights/charting-the-global-energy-landscape-to-2050-sustainable-fuels>
16. OECD/FAO. OECD-FAO Agricultural Outlook 2022-2031, 2022. OECD Publishing, Paris, <https://doi.org/10.1787/f1b0b29c-en>
17. Zheliezna T., Drahniev S. Current state and prospects for the production of motor biofuels in Ukraine. *Journal of Science*. Lyon, 2023, No 42, p. 34-38, <https://doi.org/10.5281/zenodo.7898728>
18. Technology Data for Renewable fuels. Danish Energy Agency. Available at: <https://ens.dk/en/our-services/projections-and-models/technology-data/technology-data-renewable-fuels>
19. Temirbekova M.N., Wójcik W. Power-generating fuel based on the processing of municipal solid waste organic components. *Eurasian phys. tech. j.*, 2021. Vol. 18, No. 3, pp. 53-59, <https://doi.org/10.31489/2021No3/53-59>
20. Motola V., Hurtig O., Scarlat N. et al. Clean Energy Technology Observatory: Advanced biofuels in the European Union – 2023 Status Report on Technology Development, Trends, Value Chains and Markets. JRC, 2023. Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/672584, <https://publications.jrc.ec.europa.eu/repository/handle/JRC135082>
21. Brown A., Waldheim L., Landälv I. et al. Advanced Biofuels – Potential for Cost Reduction. IEA Bioenergy, 2020, https://www.ieabioenergy.com/wp-content/uploads/2020/02/T41_CostReductionBiofuels-11_02_19-final.pdf
22. The European biomass puzzle – Challenges, opportunities and trade-offs around biomass production and use in the EU. EEA, 2023. Publications Office of the European Union, Luxembourg, 2023, <https://www.eea.europa.eu/en/analysis/publications/the-european-biomass-puzzle>
23. Wieruszewski M., Mydlarz K. The Potential of the Bioenergy Market in the European Union – An Overview of Energy Biomass Resources. *Energies*, 2022. 15(24), 9601, <https://doi.org/10.3390/en15249601>
24. Shehab M., Moshammer K., Franke M., Zondervan E. (2023). Analysis of the Potential of Meeting the EU's Sustainable Aviation Fuel Targets in 2030 and 2050. *Sustainability*, v. 15, N 12: 9266. <https://doi.org/10.3390/su15129266>
25. Detsios N., Theodoraki S., Maragoudaki L. (2023). Recent Advances on Alternative Aviation Fuels/Pathways: A Critical Review. *Energies*, v. 16, N 4: 1904. <https://doi.org/10.3390/en16041904>
26. Magnolo F., Dekker H., Decorte M., Bezzi G., Rossi L., Meers L., Speelman S. The Role of Sequential Cropping and Biogasdoneright™ in Enhancing the Sustainability of Agricultural Systems in Europe. *Agronomy*. 2021, 11(11), 2102. <https://doi.org/10.3390/agronomy11112102>



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