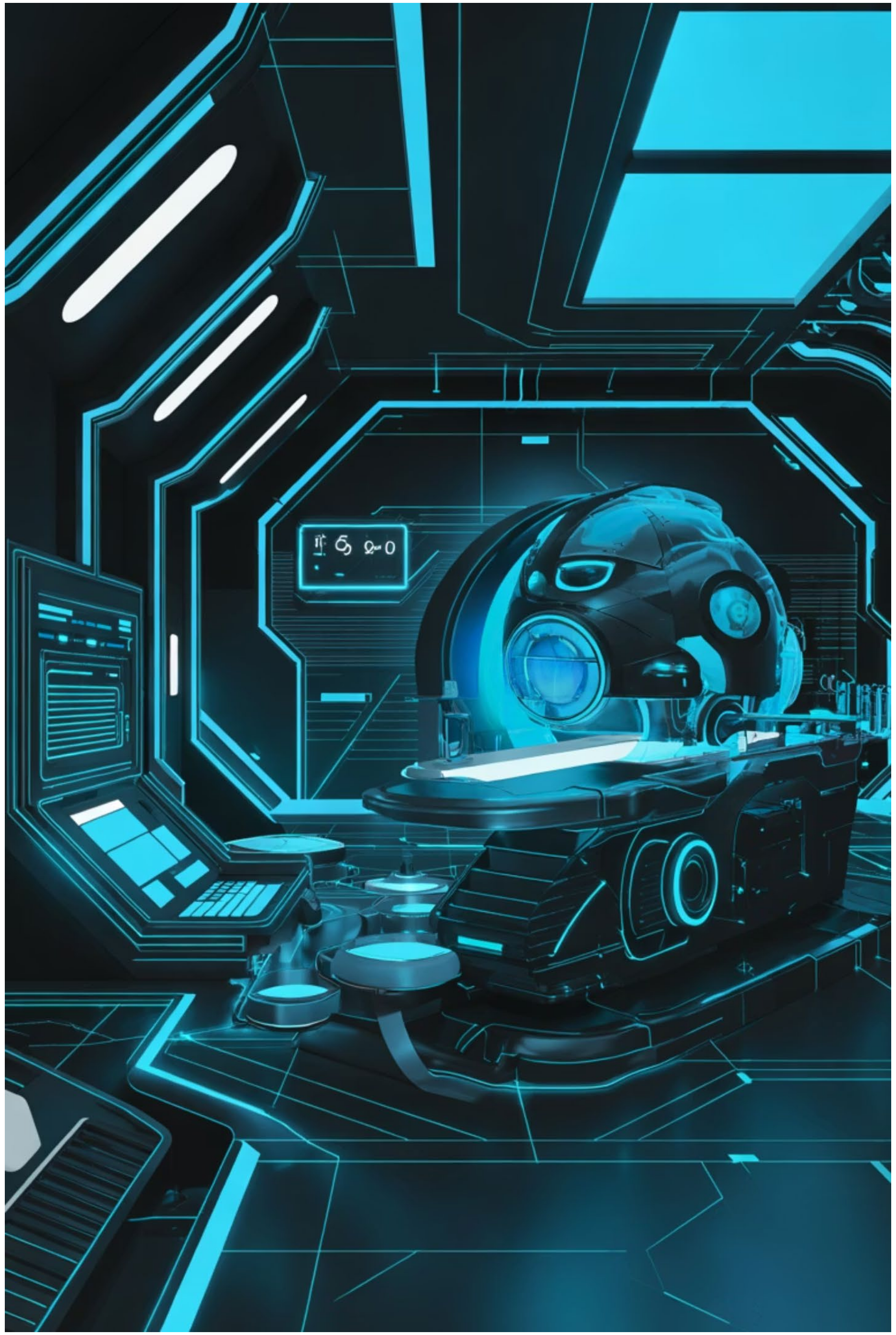


South-East Europe Initiative for Apheresis

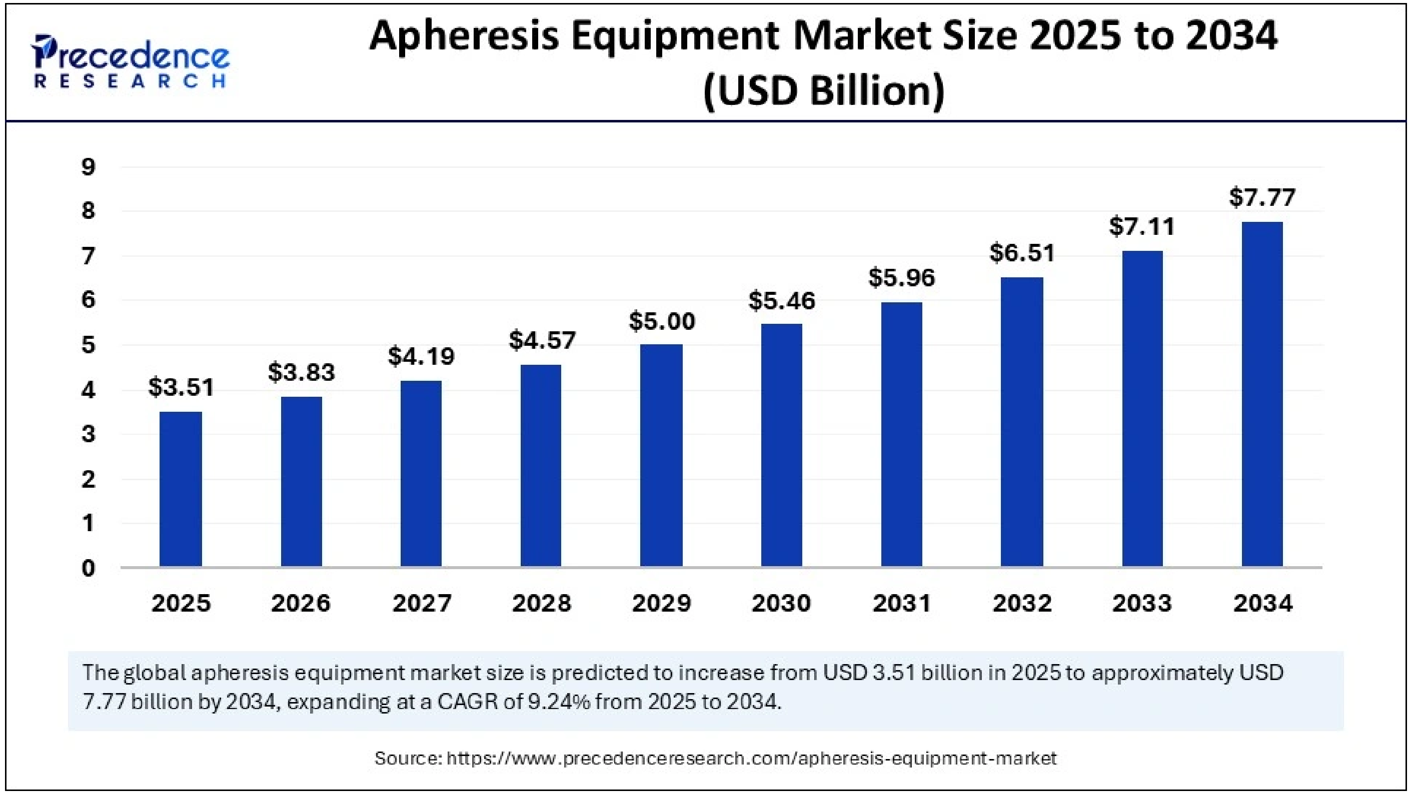
ΕΛΛΗΝΙΚΗ ΕΤΑΙΡΕΙΑ ΑΙΜΑΦΑΙΡΕΣΗΣ

10th Hellenic Haemapheresis Association Conference

AI and Apheresis

Paraskevi Tseke
Nephrologist, General Hospital of Athens
“ALEXANDRA”

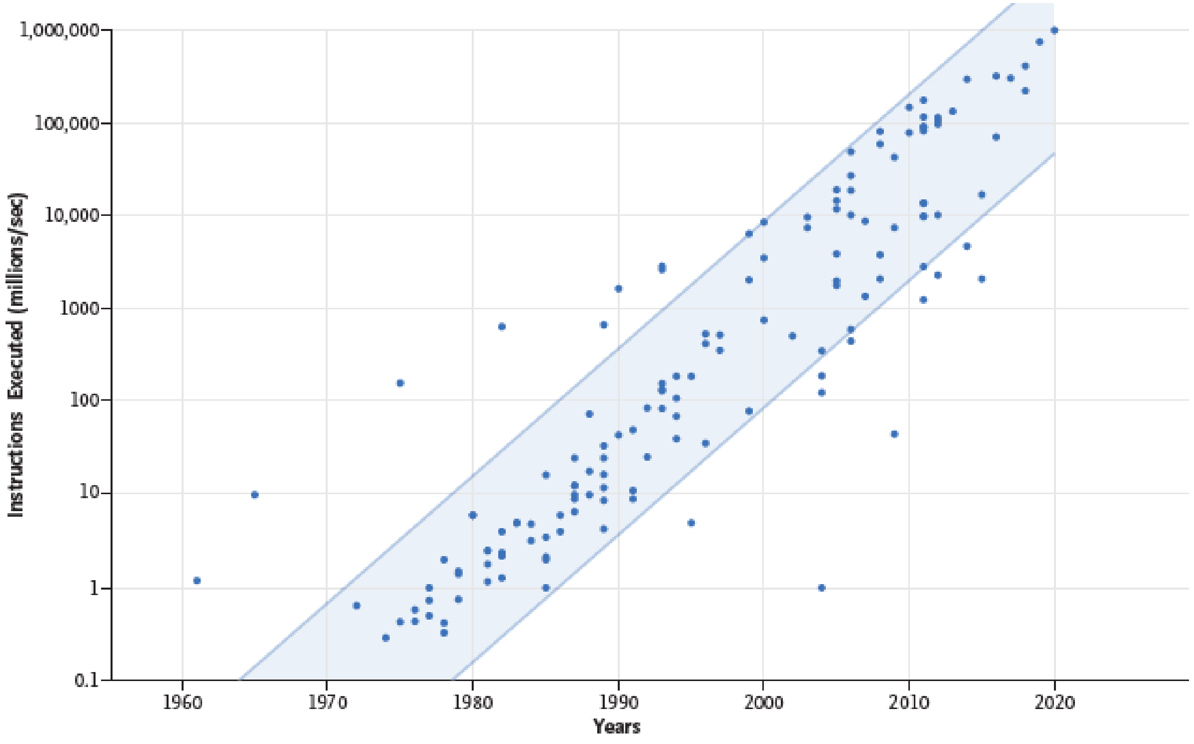
The global apheresis market growth



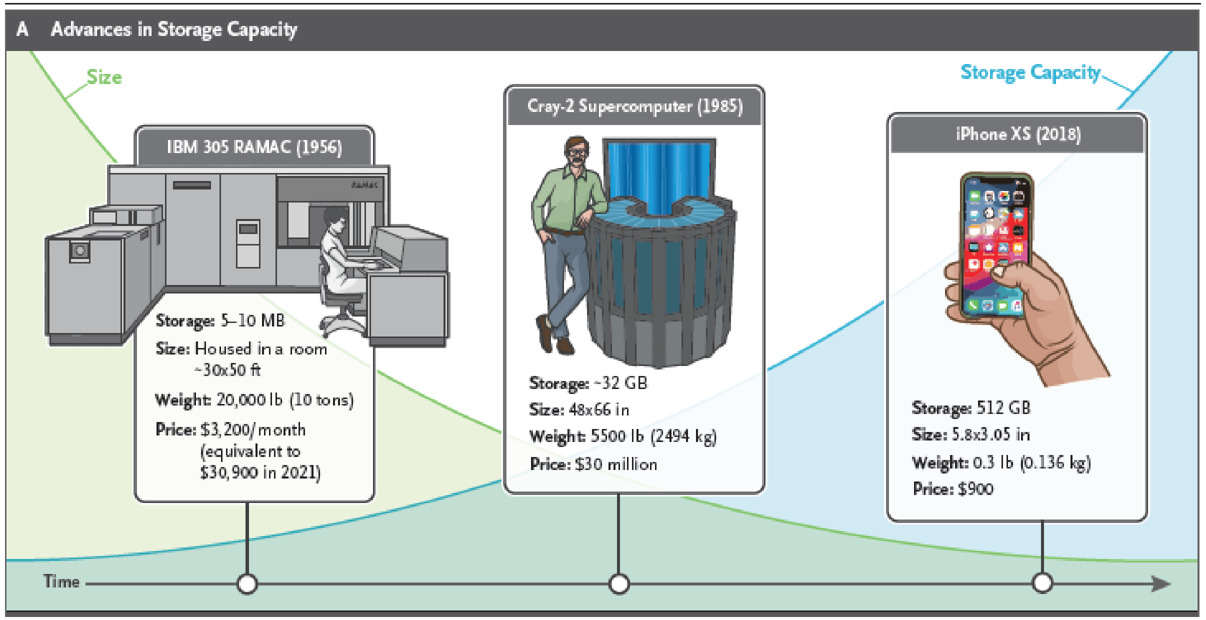
- Therapeutic plasma exchange (hematological, renal and autoimmune diseases, malignancies, neurological disorders)
- Stem cell collections
- Immune cell treatments
- Plasma collections for biopharmaceutical manufacturing
- Blood component donation

Apheresis equipment manufactures are nowadays focusing on integrating digital technologies and AI to improve their devices

Computer technology and AI growth



The NEW ENGLAND JOURNAL of MEDICINE



N ENGL J MED 388;13 NEJM.ORG MARCH 30, 2023

AI in medicine:
AI and machine learning (ML) revolutionized medicine

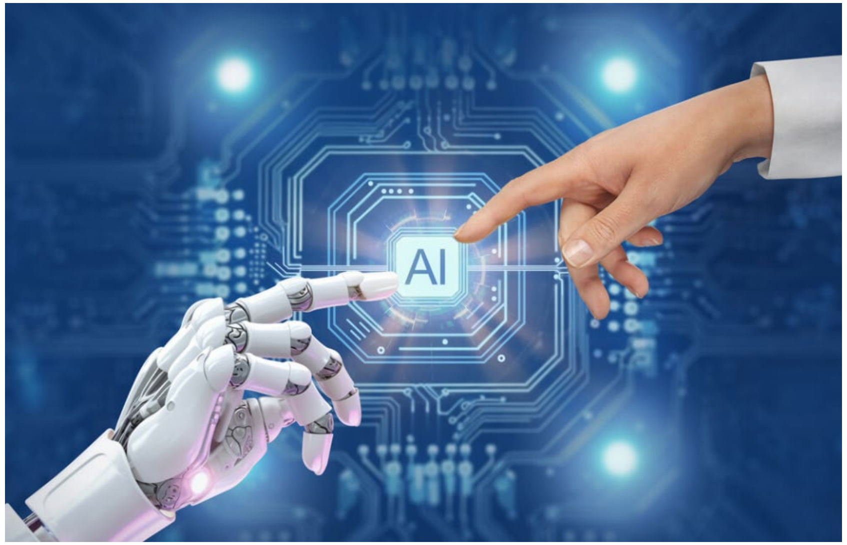
- Multiplying diagnostic capability- ensuring diagnostic accuracy- exploring predictive algorithms for early diagnosis

- Transforming clinical workflows and reducing clinicians work-load

- Providing assisting tools in medical education

- Accelerating drug discovery- optimizing clinical trials

AI in medicine:
AI and machine learning (ML) revolutionized medicine



- Enabling personalized treatments by tailoring intervention to individual patient profiles
- Reducing healthcare costs
- Aiming to bridge inequity gaps in healthcare services

What is Machine Learning (ML), Deep Learning (DL), Artificial Neural Networks (ANN)?

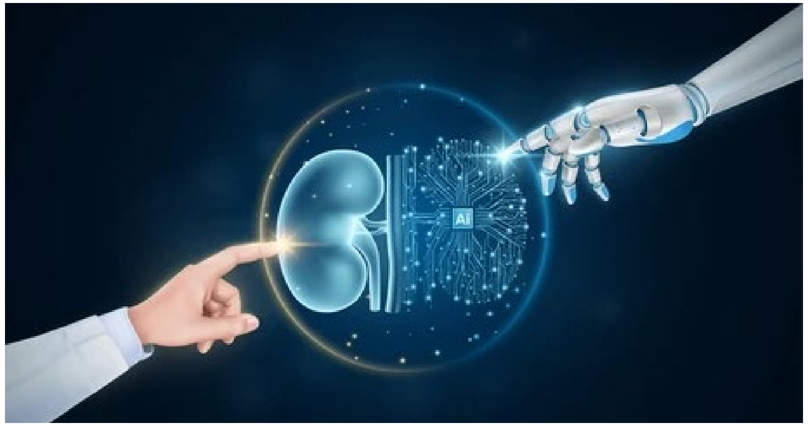
- ML: Algorithm encoding statistical regularities from a database into parameters weight for future predictions (i.e. risk prediction under provided data)

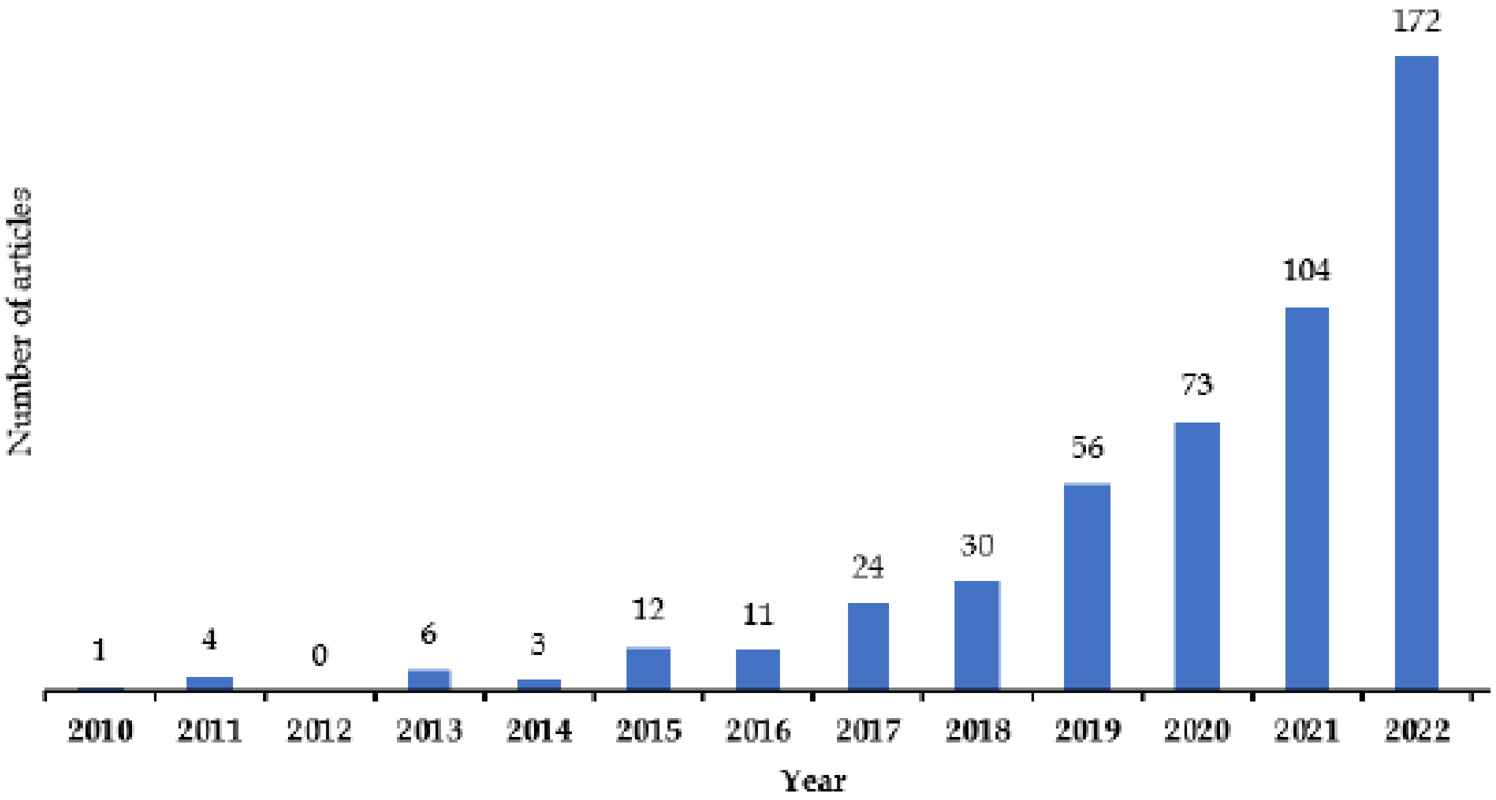
- DL: type of ML using computations to learn from large datasets without human intervention (enables machines to learn and make decisions under complex environment i.e. robotic surgery and decision making, clinical trials design)

- ANN: arrangement of neurons in layers interconnected to each others similarly to brain neurons

Diagnostics (Basel). 2023 Aug 3;13(15):2582

Annual publications on the application of AI in kidney disease





Diagnostics **2024**, *14*, 397

Plasma exchange and apheresis procedures

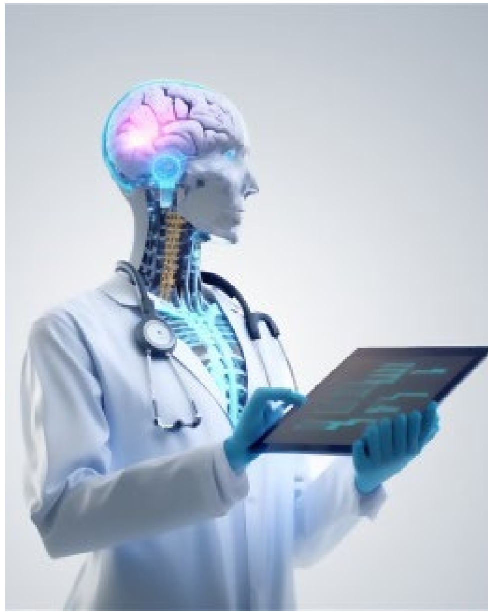
- TPE has been applied for the removal or the substitution of pathological plasma components, *but it also acts as a "reset" for immune system reducing inflammation & disease drivers rapidly*
- Apheresis is a broader category which includes all the extracorporeal blood separation and adsorption techniques
- State-of-the-art apheresis equipment:
  integrated monitoring systems
  precise control of plasma separation and replacement volumes & patient's vital parameters.

Integration of AI in Apheresis: patient selection

- <u>Collection and analysis of large datasets</u>
  - *Computational models can process large patient information from electronic health records to*
    - *recognize individual characteristics*
    - *uncover patterns*
    - *enable more personalized treatment protocols*

- <u>Enhanced patient selection</u>
  - *Machine learning algorithms allow the deep analysis of complex clinical data to identify patients who will benefit from PLEX reducing unnecessary procedures.*

- <u>Personalized treatment</u>
  - *Individualized treatment protocols based on patient condition, disease severity, response to therapy*



Integration of AI in Apheresis: procedure safety and efficiency

- <u>Dynamic monitoring and complications prevention</u>
  - *Early detection of procedural complications (electrolyte disorders, allergic reactions, hypotension)*
  - *prevention of post-procedural complications (hemostatic disorders, infections)*
  - *real-time parameter modification to ensure patient safety*
- <u>Improvement of cost effectiveness</u>
  - *Automated diagnosis,*
  - *distant patient monitoring & treatment planning and*
  - *optimization of limited resources reduce healthcare costs*
- <u>Integration with digital health systems</u>
  - *The ability of PLEX device to connect will digital heath systems and allow sharing patient information with telemedicine platforms, electronic health records etc*
- <u>Ability to predict outcomes (i.e.peripheral blood stem cell harvesting)</u>
  - *ML models have been used to identify factors predictive for successful peripheral blood collections on the first attempt reducing treatment time and number of procedures (J Int Med Res 2024;25:1-11)*


Observational Study

Journal of INTERNATIONAL MEDICAL RESEARCH

Predicting apheresis yield and factors affecting peripheral blood stem cell harvesting using a machine learning model

Journal of International Medical Research
2024, Vol. 52(12) 1–11

DOI: 10.1177/03000605241305360
journals.sagepub.com/home/imr
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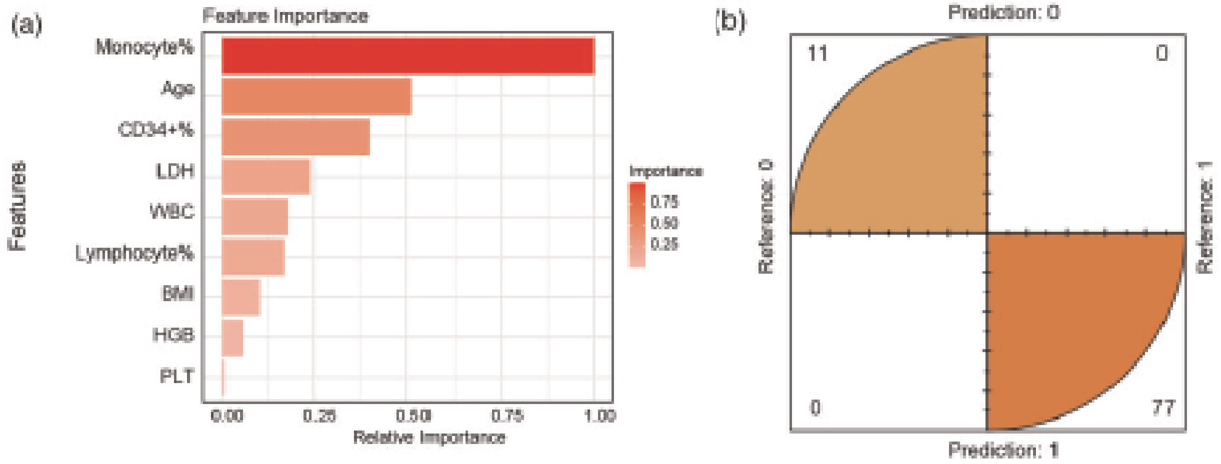


Identification of important factors influencing success of initial PBSC collection using XGBoost Algorithm (Mono%, age, CD34 cells are the leading variables – confusion matrix showing how these 3 variables can differentiate (+) and (-) outcomes

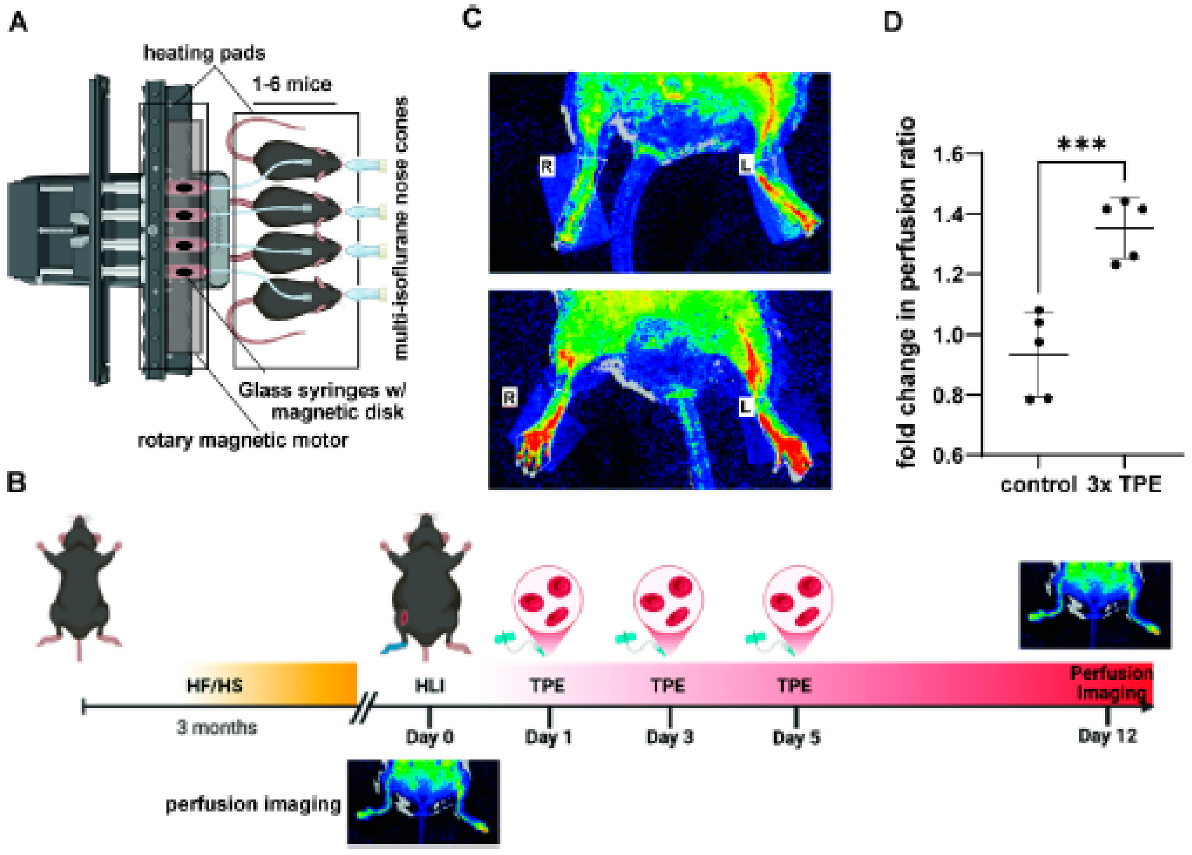
Integration of AI in Apheresis: disease intervention

- What is the role of PLEX in preventing or mitigating chronic diseases?
  - Data supporting its role in anti-aging process and its potential to mitigate age-related disorders and promote tissue rejuvenation.
  - Multi-omic-based, predictive, personalized plasma diagnostics may expand the spectrum of conditions treated with apheresis (chronic inflammatory metabolic diseases)

- Preclinical models in mice showed evidence of innate system modulation that promotes brain tissue resilience and repair *(Geroscience 2021;1-18).*
  - AI technology could possibly assist in generating “synthetic patients” & “digital twins”; simulation models to predict outcomes in humans
  - Modelling complex biological systems (i.e. protein folding) using quantum computing could also provide accurate simulation of biological procedures

- Crossing the barriers – on site targeted adsorption techniques
  - Robotic assisted techniques & nano-vehicles to cross certain barriers i.e. blood-brain barrier and enable on site specific therapeutic techniques

Here is an experimental example



- Automated PEs in murines: Improve in diabetic limb ischemia and vascular injury
- AI tools assisted in modelling micro-apheresis techniques and analyzing images
- AI could simulate synthetic diabetic patients to predict possible effect in humans

Biomolecules 2025;1-30

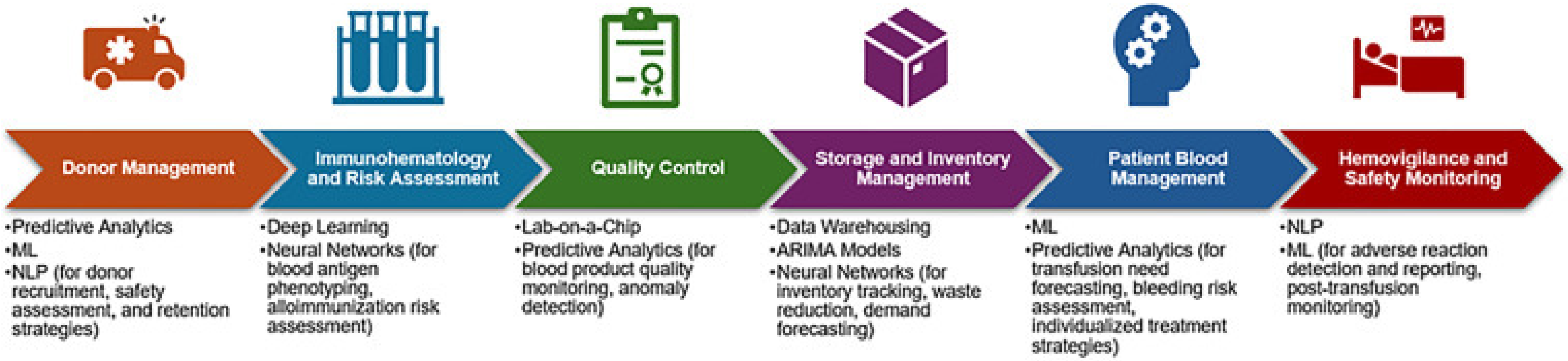
AI in transfusion medicine

AI-powered systems enable:

1) Accurate blood antigen phenotyping

2) Automated hemovigilance workflows

3) Streamline inventory management through advanced forecasting models.



Key stages of TM and AI applications in every stage *(Acta Haematol. 2025 May 9:1–11)*

AI in transfusion medicine

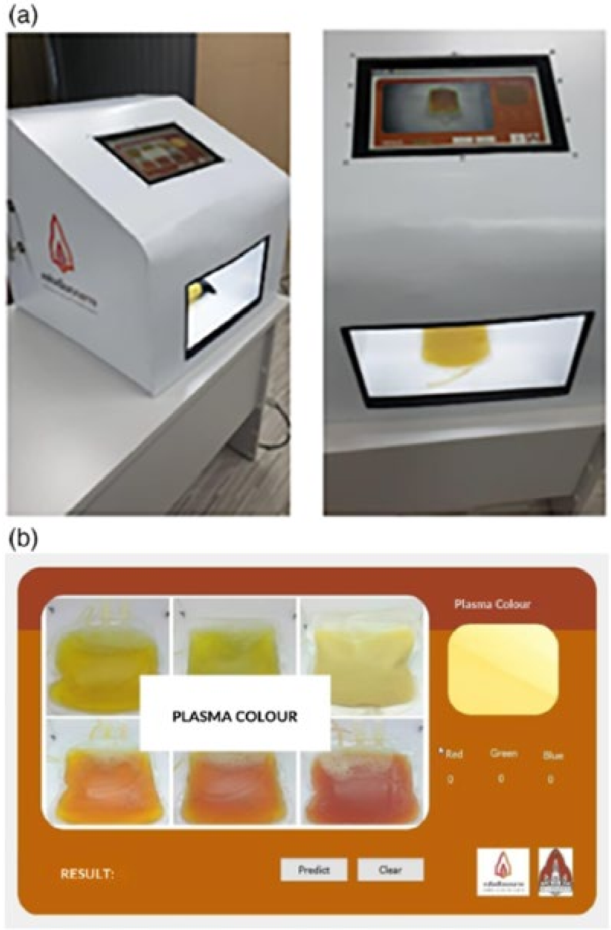


FIGURE 1 Automated plasma quality control (QC) system. (a) Schematic diagram of the plasma sorting machine with integrated artificial intelligence (AI) QC system. (b) Representative images of normal and abnormal plasma units captured by the system under standardized lighting conditions.

Vox Sang. 2025 Sep 29. doi: 10.1111/vox.70122

Technology	Applications
Machine learning (ML)	Predicting transfusion needs, assessing bleeding risk, donor management, and inventory optimization
Deep learning	Enhancing diagnostic accuracy in immunohematology, blood typing, and quality control of stored blood products
Neural networks	Forecasting platelet demand, assessing blood product viability
Natural language processing (NLP)	Extracting relevant details from clinical notes, automating hemovigilance reporting, and analyzing donor records
Predictive analytics	Assessing bleeding risk, forecasting transfusion needs, and optimizing PBM
ARIMA models	Time-series forecasting for platelet demand and inventory management
Lab-on-a-chip	Evaluating RBC quality through real-time monitoring of cellular integrity and biochemical markers
Data warehousing and integration	Streamlining inventory tracking, supporting hemovigilance workflows, and improving supply chain coordination

Acta Haematol. 2025 May 9:1–11

What should we expect in the near future?

Could AI assisted TPE be the next step in modifying chronic diseases' progression with the application of personalized clinical protocols ?

Future of TPE in Neurology

- AD (autoimmune dysautomomia), a group of acquired autonomic nervous system dysfunction disorders with no effective treatment

- AMBAR trial showed 1-year clinical benefit in pts treated with 6 TPE sessions possibly via modulation of innate immune tone and elevation of circulating proteomics implicated in neurogenesis and repair *(Alzheimer's Dement.2020;1412-25)*

- AI simulation models could help to identify specific indicators of responsiveness and even integrate selective technologies targeted to key neurological factors

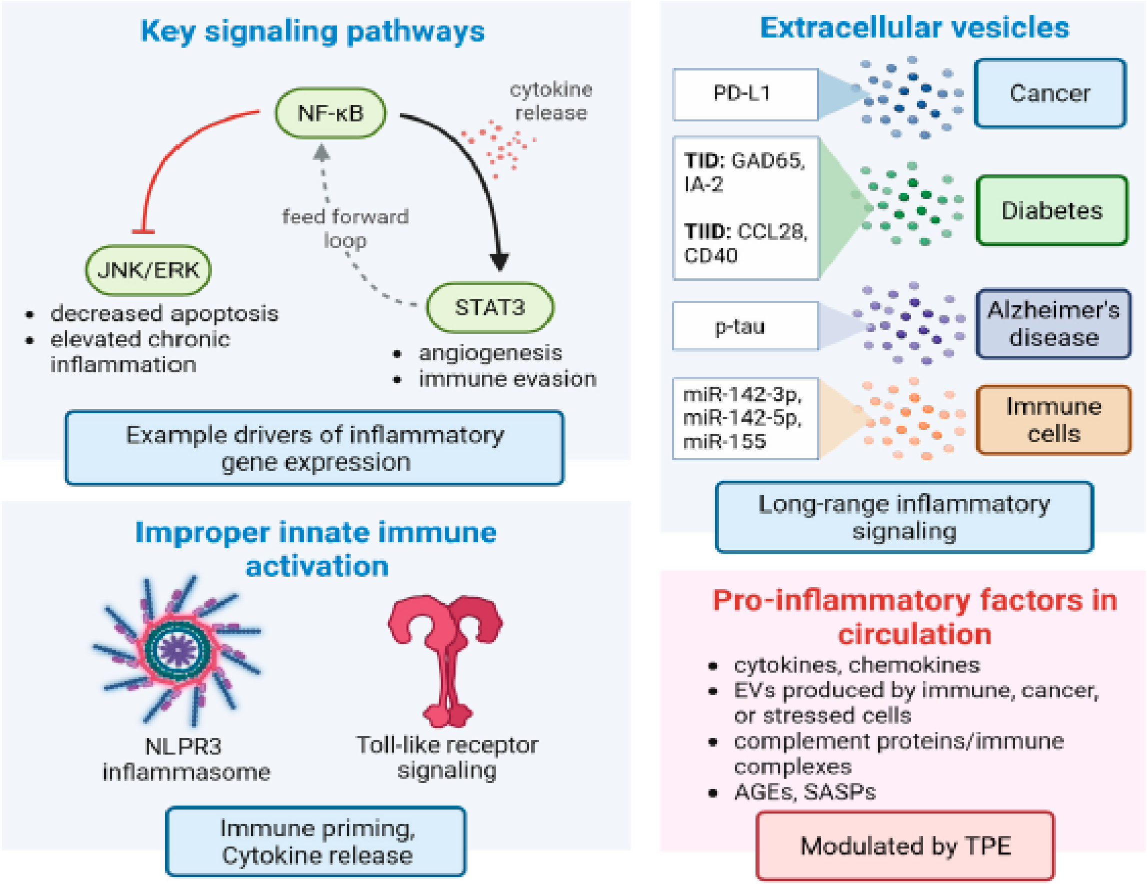
Future of TPE in diabetes and metabolic diseases

- Current indications involve hypertriglyceridic pancreatitis and familial hypercholesterolemia
- LDL apheresis acutely lowers LDL, Lp(a), but also removes PCSK9, AGEs, ox-LDL, inflammatory adipokines modulating atherosclerotic disease progression.
- There are little data available regarding the effect of TPE in diabetes (type I & II)
- AI models could predict removal of several metabolomics involved in diabetes and metabolic diseases exploring new possible indications

Future of TPE in oncology

- Glycolytic metabolism and the generation of H+ and lactate favor tumor growth - many anticancer drugs inhibit glycolysis
- TPE has been shown to reduce lactic acid levels in septic patients- what about tumor acidosis?
- Could TPE modify tumor-microenviroment and mitigate its metabolism?
- There is evidence that TPE using b2-macroglobulin filter could reduce tumor cell counts and EVs associated with resistance to immune checkpoint inhibitors
- Real-time monitoring of tumor responses using TPE could provide information about its potential role in cancer therapies

Overview of signaling pathways and inflammatory factors potentially altered by TPE



- Transcription factors regulate inflammatory gene expression and improper innate immune activation
- Cytokine release through innate immune sensors.
- EVs produced by immune, cancer or stressed cells carry pro-inflammatory factors.
- TPE reduces inflammatory factors and EVs and promotes immune modulation (increasing Tregs, and TH2 shift) resulting in a regenerating environment

biomolecules 2025;1-30

AI-assisted education in apheresis

Transfusion and Apheresis Science 64 (2025) 104188

Contents lists available at ScienceDirect

Transfusion and Apheresis Science

journal homepage: www.elsevier.com/locate/transci

ELSEVIER

Comparative performance analysis of artificial intelligence models in therapeutic apheresis training: A pilot study

- First study to evaluate knowledge level & consistency of 3 AI models (ChatGPT 4o, o1 preview and Claude 3.5 Sonnet)
- 75 multiple choice questions exam from official pool for apheresis certification
- Accuracy rates were 61%, 67% and 59%, respectively
- Consistency was good enough between 2 runs of the models (0.70-0.76)

Although significant challenges regarding

- Accurate exploration of clinical variability/heterogeneity
- Differentiations in clinical workflows & medical practice
- Transparency in model development & decision making
- Ethical concerns about data privacy and bias, equitable access

must be addressed to ensure responsible integration of AI in apheresis

Thank you!