# ARTIFICIAL INTELLIGENCE IN TRANSFUSION MEDICINE: WHAT PERSPECTIVES FOR THE FUTURE?

EFS
ÉTABLISSEMENT FRANÇAIS DU SANG
*Du donneur aux patients*

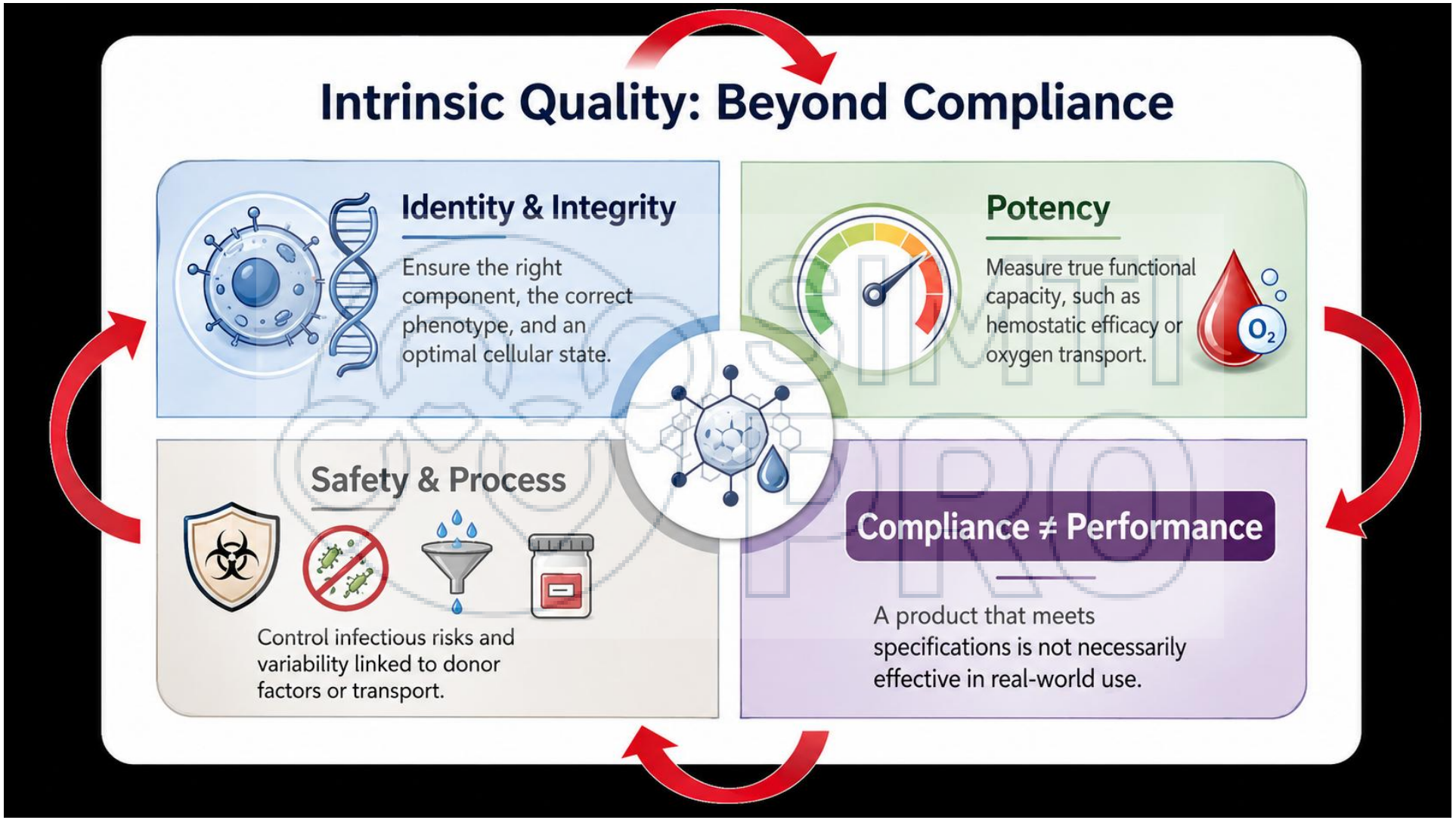
- The central question is: how can AI help transfusion medicine move from simple product conformity to patient-centred performance?

- AI is not here to replace medical expertise, but to support better, faster and safer decisions for clinicians, biologists and transfusion specialists.

**Dr Fabrice Cognasse (PhD, HDR)**
**Scientific Director – Etablissement Français du Sang Auvergne-Rhône-Alpes**
**Research Director – Etablissement Français du Sang & INSERM U1059**

**Donnons au sang *le pouvoir* de soigner**

# Intrinsic quality goes beyond formal compliance.




**For the future, we need to connect regulatory quality with clinical performance in specific patient contexts.**

# The future challenge: moving from “minimum regulatory” control to fit-for-purpose quality that predicts clinical efficacy

- **Define quality through clinical use:** the right component for the right indication (active bleeding ≠ prophylaxis ≠ immunological/inflammatory risk).
- **Move from “compliant” to “performing” quality:** complement regulatory criteria with functional and robustness indicators truly correlated with expected benefit.
- **Segment the offer and secure decisions:** accept several target qualities (e.g., haemostasis-oriented vs inflammation-oriented platelets; standard RBCs vs phenotyped/extended compatibility RBCs), with clear allocation rules.
- **Control variability (donor–process–storage):** manage the main sources of dispersion to optimise added value and reserve high-level products for situations where they change prognosis.
- **Create system value:** Fit-for-purpose means fewer losses, better continuity, and more clinical confidence, based on data.

# What we measure today (Classical QC)… and What it does not tell us

## French Official Journal No. 0136, 13 June 2025 – list and characteristics of labile blood components

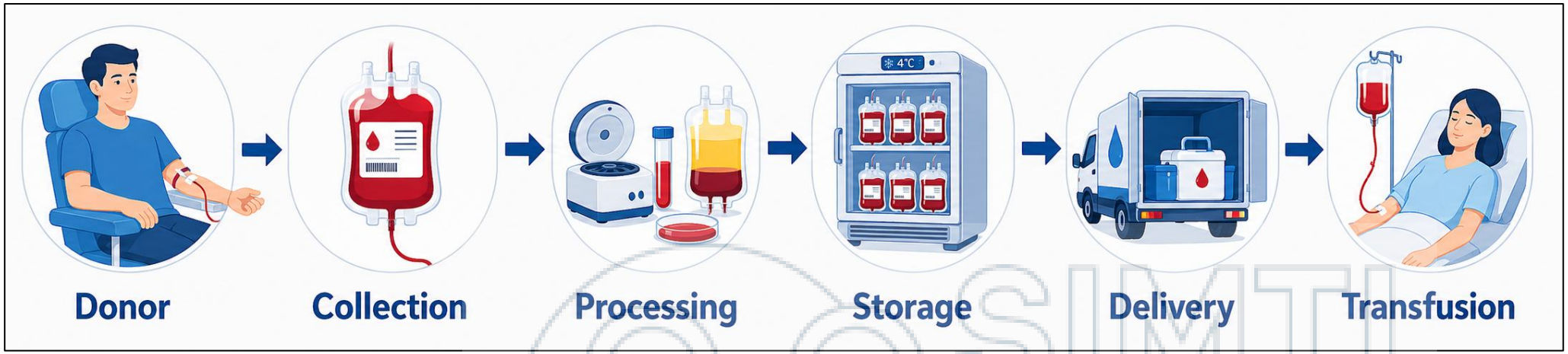
| Product family | Product | Quality control: what is measured |
|---|---|---|
| **RBC components** | RBC concentrate / paediatric, volume-reduced, plasma-reduced, irradiated, thawed and specific additive-solution variants | Haemoglobin (g); haematocrit (%); residual leukocytes (/unit); haemolysis (%); residual proteins (g); residual glycerol (g) |
| **Platelet components** | Pooled or apheresis platelets, with additive solution, divided, thawed, volume-reduced, plasma-reduced, irradiated, pathogen-reduced and paediatric variants | Volume (mL); pH at 22°C at end of storage; platelet content; concentration (G/L); residual leukocytes; residual proteins; residual amotosalen; unit visual control (swirling, colour, absence of clots) |
| **Plasma** | Quarantined, apheresis, amotosalen/UVA-treated, pooled, thawed, lyophilised, fractionation and autologous plasma variants | Volume; factor VIII (IU/mL); fibrinogen (g/L); residual leukocytes, platelets and RBCs; residual amotosalen; residual moisture; reconstitution time; post-reconstitution FVIII/fibrinogen; total proteins |

Regulatory QC is essential for conformity and safety, but it remains a “minimum vital standard”: it is not sufficient to predict clinical performance.

### Concrete examples

- **RBCs:** correct Hb/Hct and haemolysis below threshold do not guarantee in-vivo survival, deformability, microcirculation or oxygen delivery.
- **Platelets:** content + pH + swirl reflect minimum viability, but imperfectly predict flow-dependent haemostasis, increment/CCI and pro-inflammatory/activation potential.
- **Plasma:** FVIII/fibrinogen and residual cells do not capture global function — pro/anti-coagulant balance, thrombin generation or endothelial effects.

# Where Quality Is Gained or Lost: the Vein-to-Vein Chain




Donor variability and stress

Stress induced by component preparation

Storage lesions of blood components

Recipient variability, stress and disease context

- **A modern quality strategy must collect and integrate data across the entire process.**
- **AI becomes relevant when we want to combine these many weak signals into useful prediction.**

EHA2025
Congress

June 12 - 15, 2025
Milan, Italy

**Session - Transfusion: What's in a bag?**

**in platelet concentrate and does it matter?**

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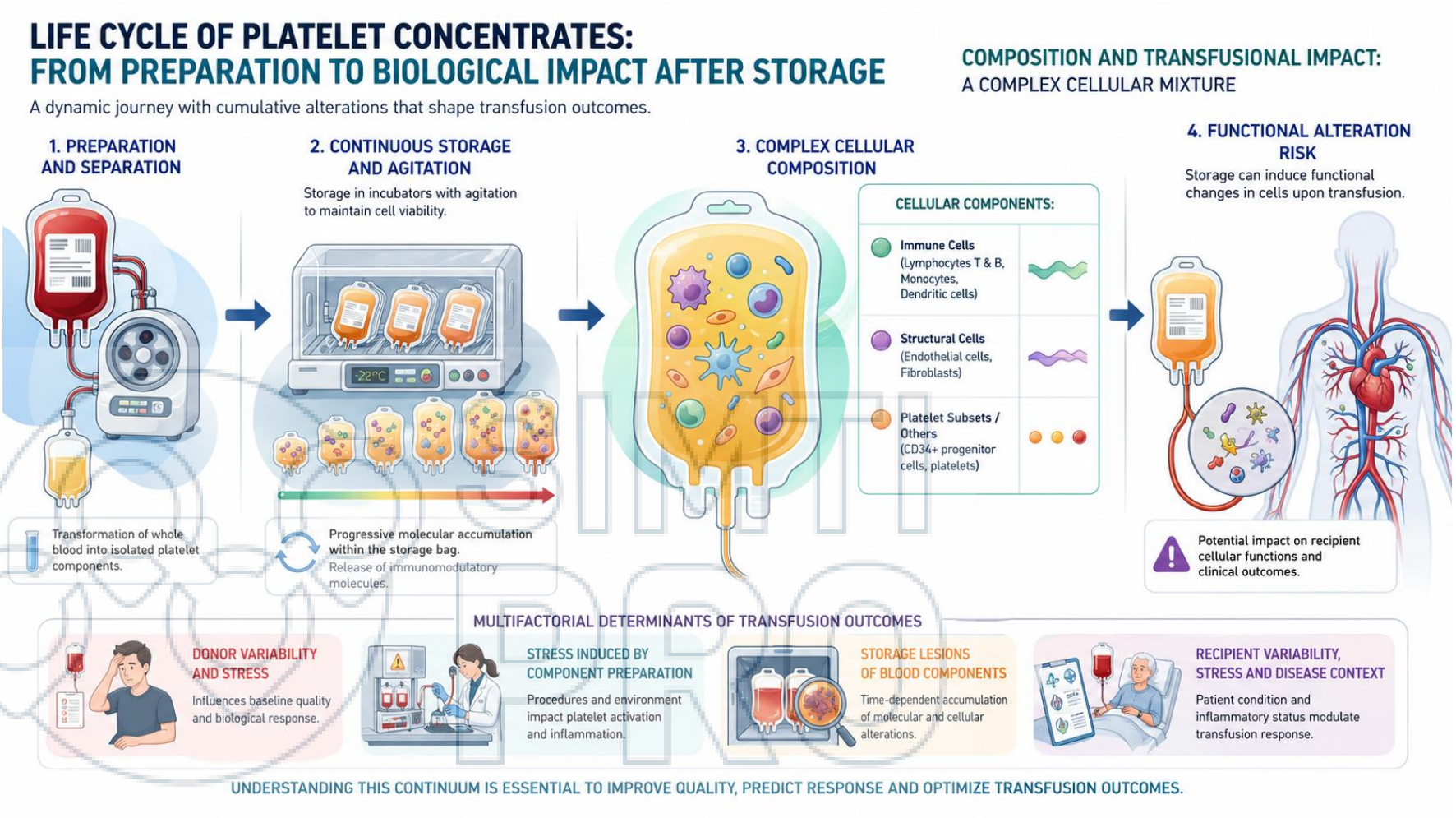
https://www.linkedin.com/search/results/all/?keywords=cognasse%20and%20EHA&origin=GLOBAL_SEARCH_HEADER




- **Proteomic signature (soluble CD40 ligand / OX40L / IL-27 / HMGB1)**
- **Lipidomic signature**
- **Mitochondrial DNA / extracellular mitochondria**
- **Microparticles**
- **MicroRNAs**

**The challenge is to connect these markers with the recipient profile and clinical outcomes.**

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# Proteomic signature (soluble CD40 ligand / OX40L / IL-27 / HMGB1)

blood

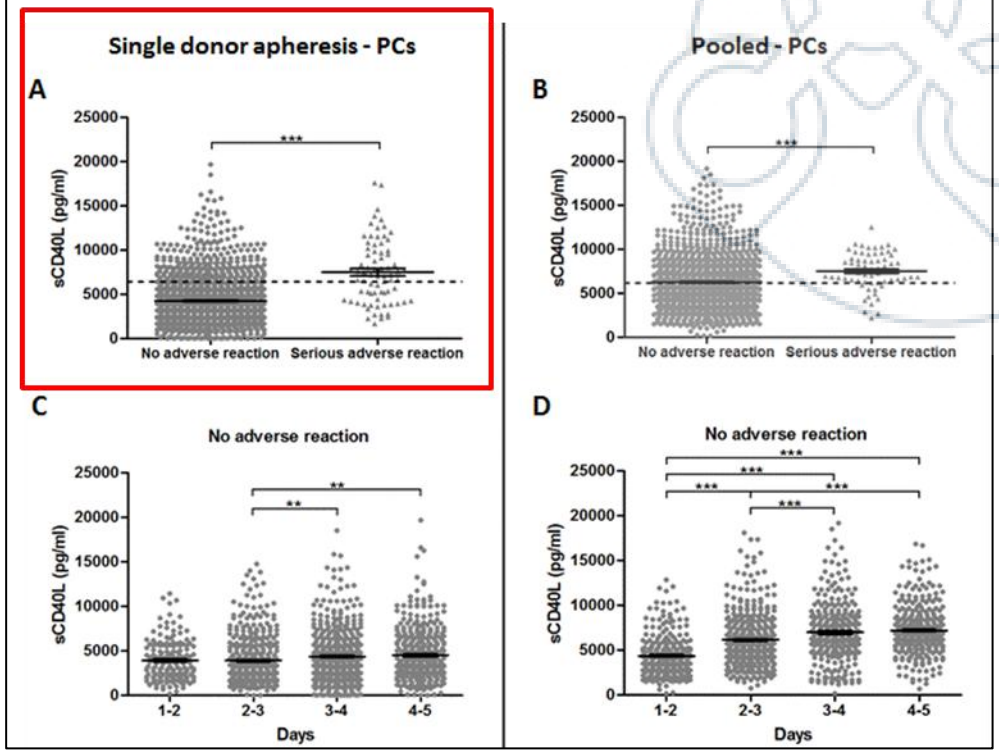
BLOOD, 14 SEPTEMBER 2017 • VOLUME 130, NUMBER 11

**Platelet soluble CD40-ligand level is associated with transfusion adverse reactions in a mixed threshold-and-hit model**

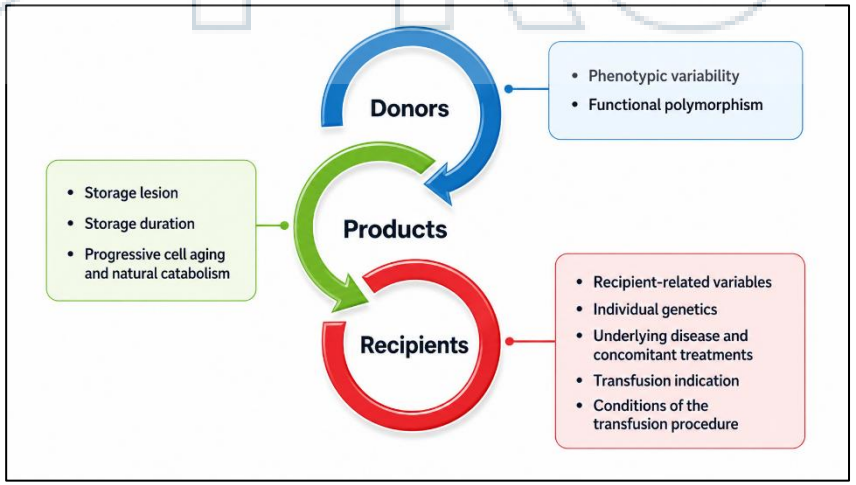
Fabrice Cognasse,[1,2] Caroline Sut,[1,2] Elisa Fromont,[3] Sandrine Laradi,[1,2] Hind Hamzeh-Cognasse,[2] and Olivier Garraud[2,4]

[1]Etablissement Français du Sang Auvergne-Rhône-Alpes, Saint-Etienne, France; [2]Université de Lyon, GIMAP-EA3064, Saint Etienne, France; [3]Laboratoire Hubert Curien - UMR CNRS 5516, Saint Etienne, France; and [4]Institut National de Transfusion Sanguine, Paris, France

| Days | No adverse reaction** (n=2710) | | Serious adverse reaction*** (n=140) | |
|---|---|---|---|---|
| | Single donor apheresis-PCs° | Pooled-PCs°° | Single donor apheresis-PCs° | Pooled-PCs°° |
| [1-2[* | 162 | 269 | 6 | 13 |
| [2-3[ | 402 | 395 | 15 | 12 |
| [3-4[ | 491 | 279 | 25 | 20 |
| [4-5] | 377 | 335 | 29 | 20 |
| Total (n=2850) | 1432 | 1278 | 75 | 65 |




- This study shows that sCD40L levels alone do not fully predict adverse transfusion reactions.
- It leaves open the possibility that recipient comorbidities, genetic susceptibility, pre-existing underlying disease, or combinations of these factors may contribute to severe adverse reactions.




**The transfusion triad: "donors–products–recipients".**

ELSEVIER MASSON

Disponible en ligne sur SciVerse ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

TRANSFUSION CLINIQUE ET BIOLOGIQUE

Transfusion Clinique et Biologique 20 (2013) 231–238

État de l'art

Transfusion sanguine et inflammation

*Blood transfusion and inflammation*

O. Garraud[a,*,b], F. Cognasse[a,b], H. Hamzeh-Cognasse[b], S. Laradi[a,b], B. Pozzetto[b], J.-Y. Muller[c]

[a] Établissement français du sang (EFS) Auvergne-Loire, 25, boulevard Pasteur, 42023 Saint-Étienne cedex 2, France

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[c] Établissement français du sang (EFS), 93218 la Plaine-Saint-Denis, France

Disponible sur Internet le 12 avril 2013

# Proteomic signature (soluble CD40 ligand / OX40L / IL-27 / HMGB1)

Received: 21 April 2022 | Revised: 22 July 2022 | Accepted: 24 October 2022
DOI: 10.1111/trf.17200

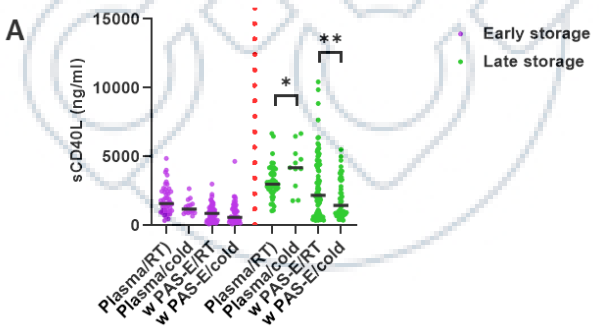
BLOOD COMPONENTS

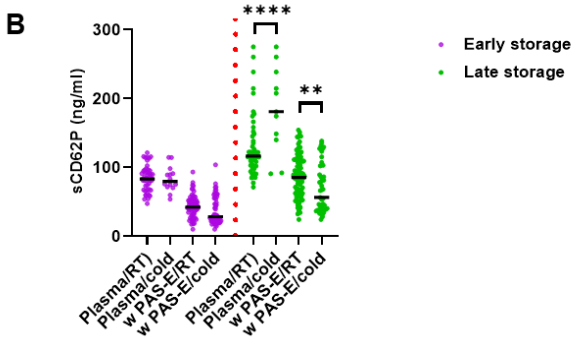
TRANSFUSION

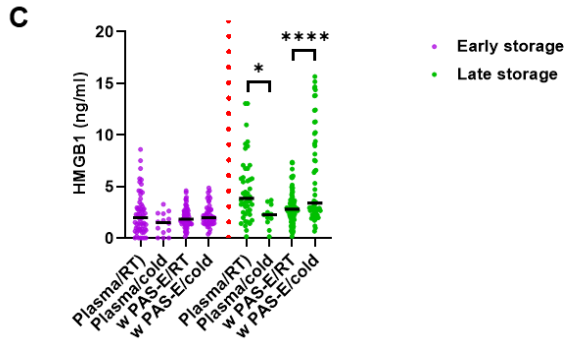
## Assessment of the soluble proteins HMGB1, CD40L and CD62P during various platelet preparation processes and the storage of platelet concentrates: The BEST collaborative study

Fabrice Cognasse[1,2] | Hind Hamzeh Cognasse[2] | Marie Ange Eyraud[1,2] | Amélie Prier[1,2] | Charles Antoine Arthaud[1,2] | Pierre Tiberghien[3,4] | Stephane Begue[3] | Dirk de Korte[5] | Eric Gouwerok[5,6] | Andreas Greinacher[7] | Konstanze Aurich[7] | Femke Noorman[8] | Larry Dumont[9,10] | Kathleen Kelly[9,10] | Marc Cloutier[11] | Renée Bazin[11] | Rebecca Cardigan[12] | Sian Huish[12] | Peter Smethurst[12] | Dana Devine[13] | Peter Schubert[13] | Lacey Johnson[14] | Denese C. Marks[14] | Biomedical Excellence for Safer Transfusion (BEST) Collaborative


BEST Collaborative




Letter to the Editor

Page 1 of 2

## Platelet-derived HMGB1: critical mediator of SARs related to transfusion

Fabrice Cognasse[1,2], Caroline Sut[1,2], Hind Hamzeh-Cognasse[2], Olivier Garraud[2]

[1]Etablissement Français du Sang Auvergne-Rhône-Alpes, Saint-Etienne, France; [2]GIMAP-EA3064, Université de Lyon, Saint-Étienne, France
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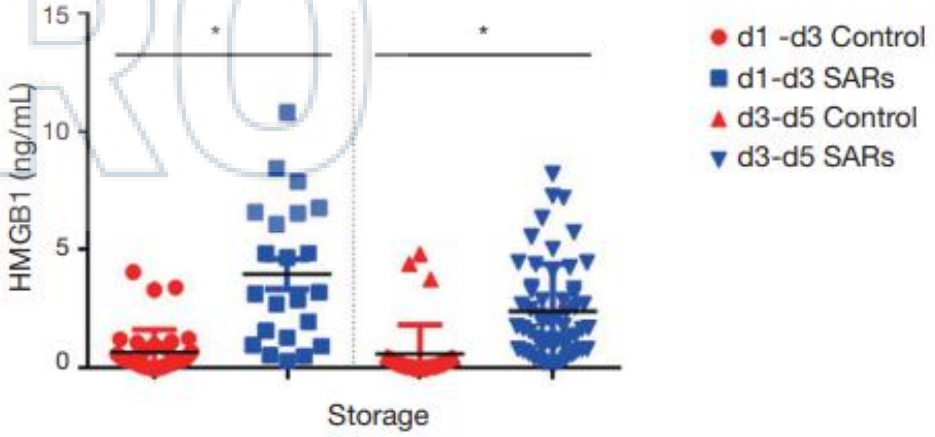


# Lipidomic signature

frontiers | Frontiers in Immunology

TYPE Original Research
PUBLISHED 17 April 2023
DOI 10.3389/fimmu.2023.1031968

Bioactive lipids as biomarkers of adverse reactions associated with apheresis platelet concentrate transfusion

Anne-Claire Duchez[1,2*], Sébastien Fauteux-Daniel[1,2], Caroline Sut[1], Theo Ebermeyer[2], Marco Heestermans[1,2], Charles-Antoine Arthaud[1,2], Marie-Ange Eyraud[1,2], Amélie Prier[1,2], Estelle Audoux[1,2], Justine Bertrand-Michel[3,4], Bernard Payrastre[4,5], Olivier Garraud[2], Eric Boilard[6,7], Hind Hamzeh-Cognasse[2] and Fabrice Cognasse[1,2]

COLLECTION, PRODUCTION AND STORAGE OF BLOOD COMPONENTS

*Original article*

**Lipidomic analysis of differently prepared platelet concentrates in additive solution during storage**

Anne-Claire Duchez[1,2], Sébastien Fauteux-Daniel[1,2], Theo Ebermeyer[2], Marco Heestermans[1,2], Charles-Antoine Arthaud[1,2], Marie-Ange Eyraud[1,2], Amélie Prier[1,2], Estelle Audoux[1,2], Jean-Charles Portais[2,4], Justine Bertrand-Michel[3,4], Olivier Garraud[1,2], Hind Hamzeh-Cognasse[2], Eric Boilard[6,7], Fabrice Cognasse[1,2]

Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Immunology

Review

**Inflammation induced by lipid mediators and protein from transfusion products**☆

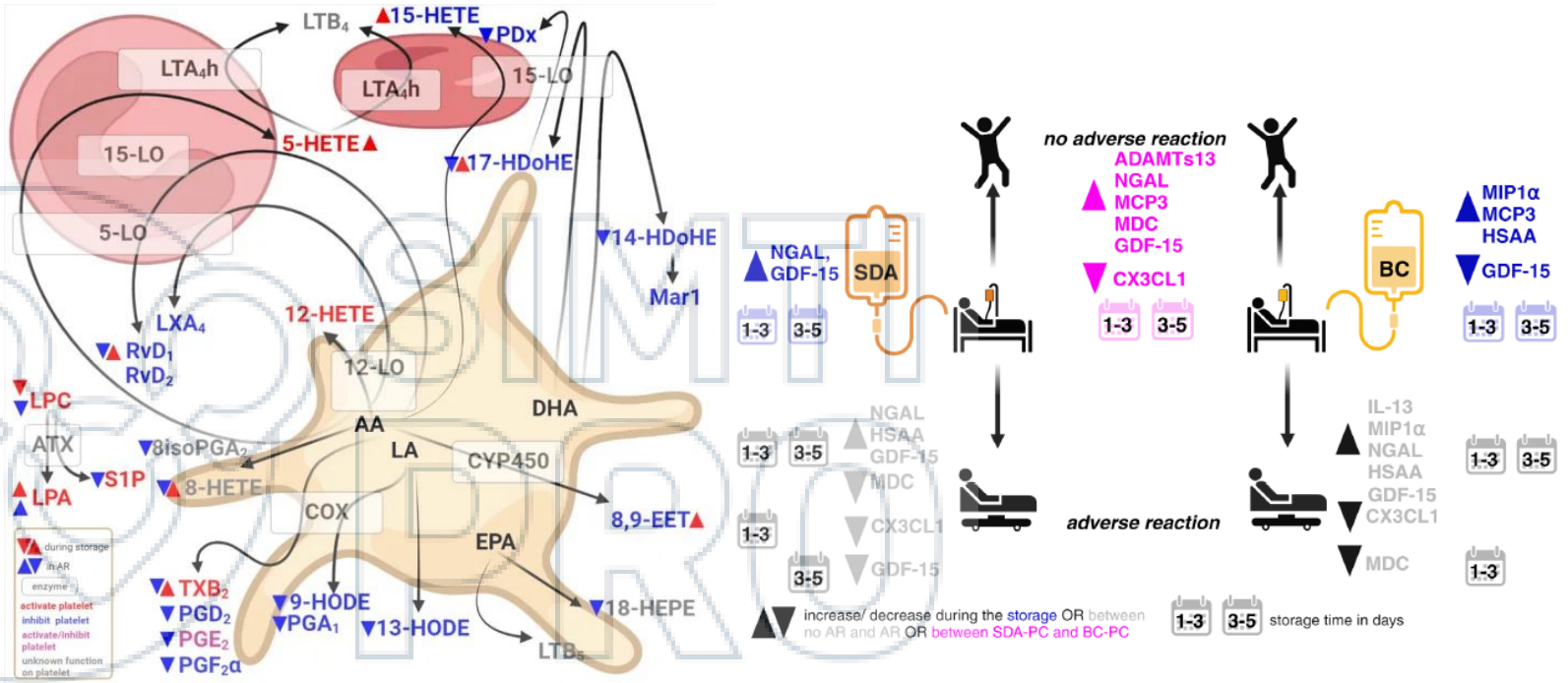
Chloe Heranney[1], Mailys Portier[1,2], Fabrice Cognasse[1,2] and Duchez Anne-Claire[1,2]

scientific reports

OPEN

**Identification of new bioactive molecules in platelet preparation, storage, and transfusion reactions for improved transfusion management**

Anne-Claire Duchez[1,2], Charles-Antoine Arthaud[1,2], Marie-Ange Eyraud[1,2], Amélie Prier[1,2], Marco Heestermans[1,2], Hind Hamzeh-Cognasse[2] & Fabrice Cognasse[1,2]




- **Platelet concentrate storage profoundly remodels lipid metabolism, with potential effects on platelet activation and inflammation.**
- **Depending on product type (SDA-PC vs BC-PC) and storage duration, some soluble biomarkers evolve differently and are associated with the occurrence or absence of post-transfusion adverse reactions.**

# Mitochondrial DNA / Extracellular mitochondria

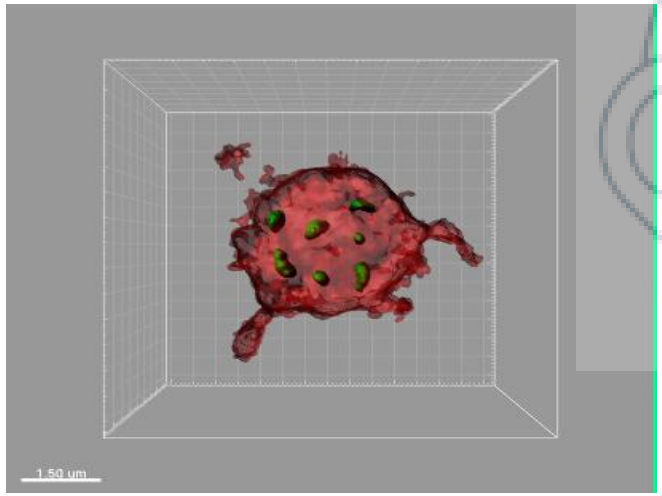
PLATELETS AND THROMBOPOIESIS

**Platelets release mitochondria serving as substrate for bactericidal group IIA-secreted phospholipase $A_2$ to promote inflammation**

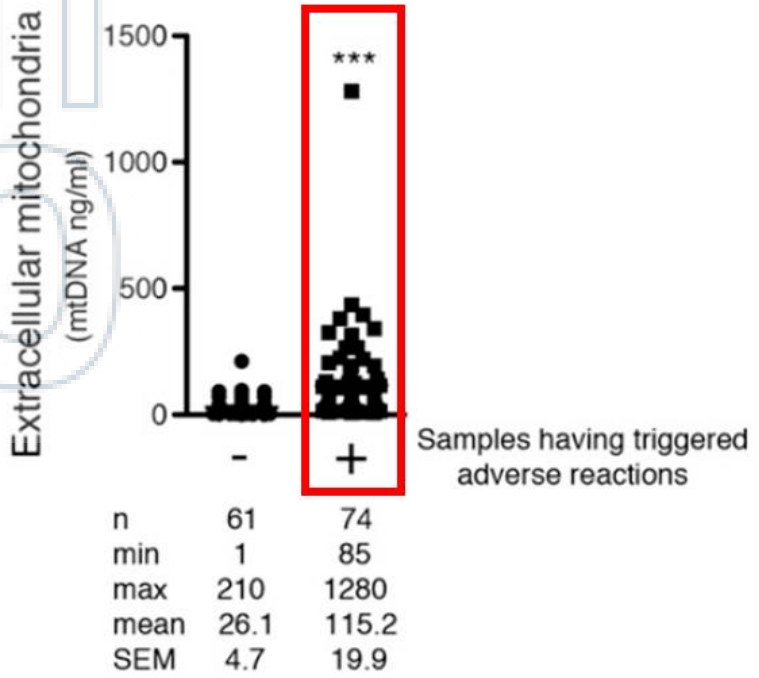
Luc H. Boudreau,[1] Anne-Claire Duchez,[1] Nathalie Cloutier,[1] Denis Soulet,[2] Nicolas Martin,[3] James Bollinger,[4] Alexandre Paré,[2] Matthieu Rousseau,[1] Gajendra S. Naika,[4] Tania Lévesque,[1] Cynthia Laflamme,[1] Geneviève Marcoux,[1] Gérard Lambeau,[5] Richard W. Farndale,[6] Marc Pouliot,[1] Hind Hamzeh-Cognasse,[7] Fabrice Cognasse,[7] Olivier Garraud,[7] Peter A. Nigrovic,[8] Helga Guderley,[3] Steve Lacroix,[2] Louis Thibault,[9] John W. Semple,[10] Michael H. Gelb,[4] and Eric Boilard[1]

**Extracellular mitochondria, produced by platelets, at the midpoint of a potent mechanism leading to inflammatory responses**

**Dr Boilard:** Centre de Recherche du Centre Hospitalier Universitaire de Québec, Faculté de Médecine de l'Université Laval, Quebec, QC, Canada

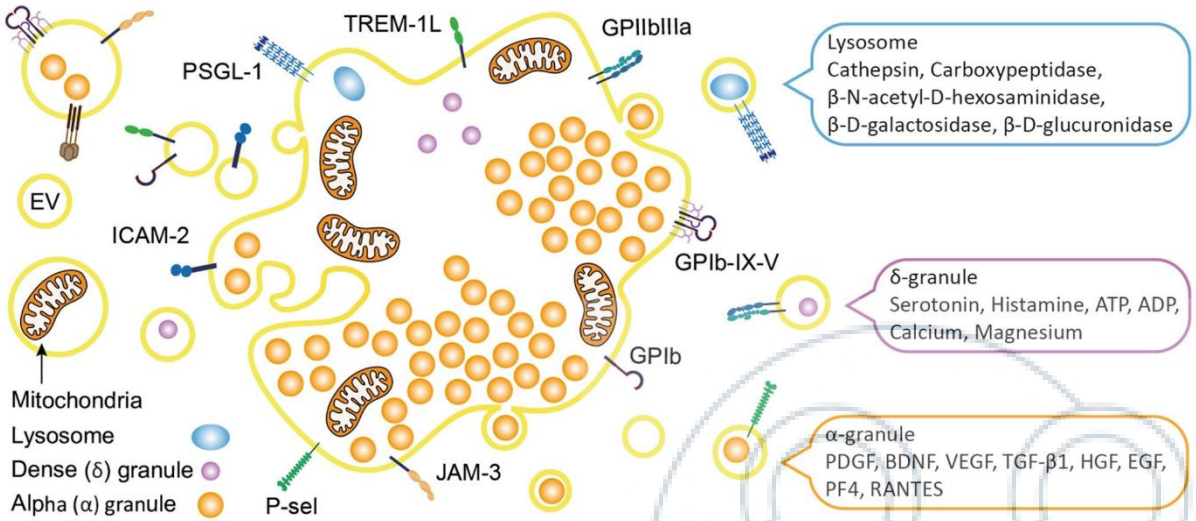



- **This major Blood publication links extracellular mitochondria released by activated platelets to the initiation of inflammatory responses during transfusion.**

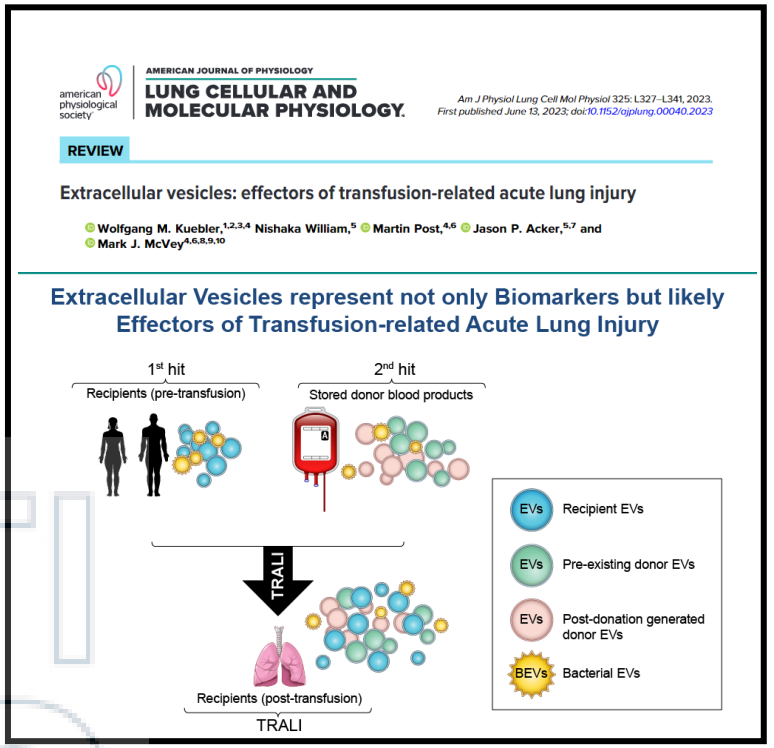



- **Extracellular mitochondria, correlated with platelet activation, could serve as biomarkers for predicting transfusion complications.**

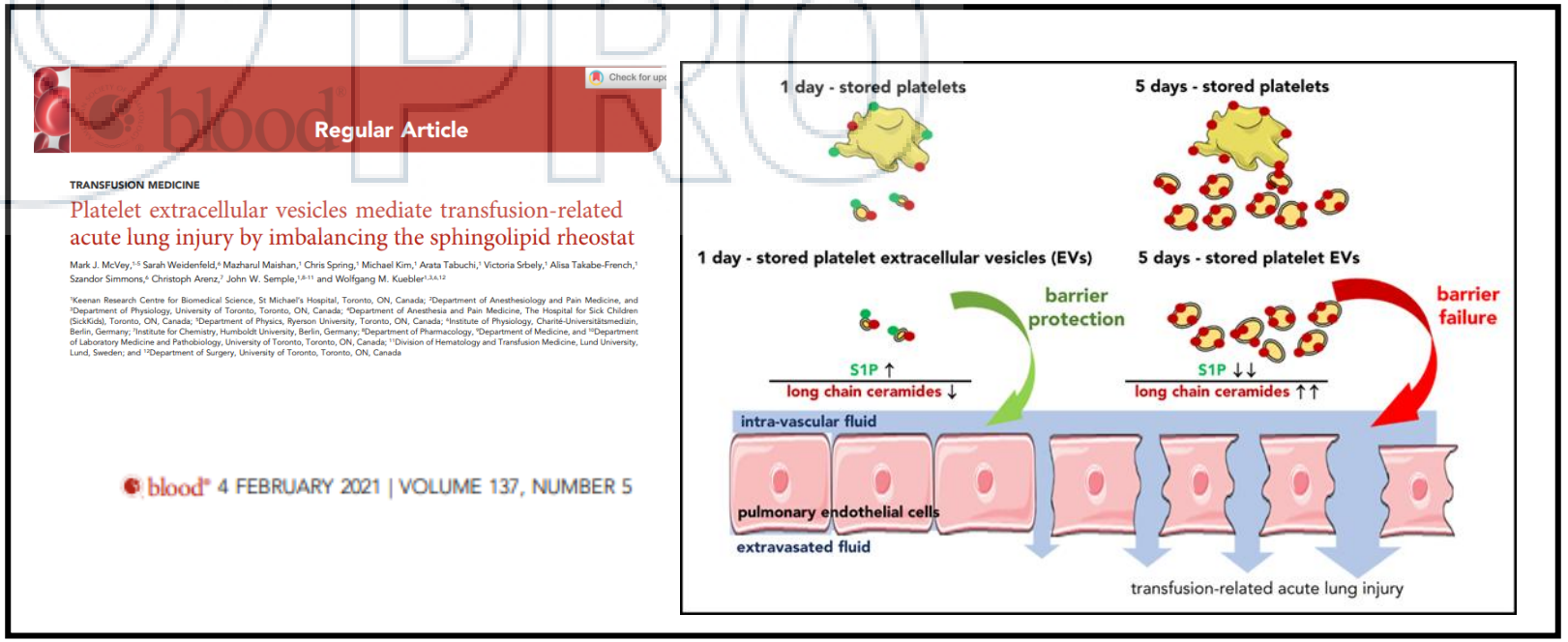
# Platelet-derived vesicles and microparticles




*Burnouf T et al., Journal of Biomedical Science, 2023*




- **Sphingolipids and microparticles regulate endothelial integrity.**
- **Platelet storage modifies the effect of platelet vesicles.**



# Platelet microRNAs

frontiers in Physiology
REVIEW
published: 15 April 2021
doi: 10.3389/fphys.2021.652579

## MicroRNA as Potential Biomarkers of Platelet Function on Antiplatelet Therapy: A Review

Pamela Czajka[1], Alex Fitas[1], Daniel Jakubik[1], Ceren Eyileten[1], Aleksandra Gasecka[2], Zofia Wicik[1,3], Jolanta M. Siller-Matula[1,4], Krzysztof J. Filipiak[2] and Marek Postula[1,4]

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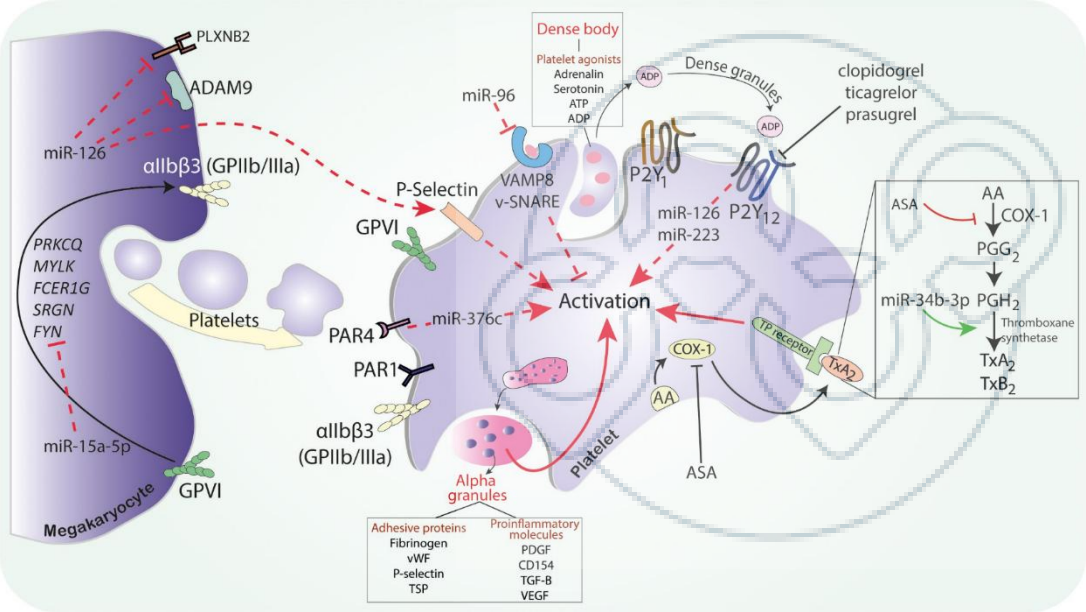


platelets
http://informahealthcare.com/plt
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Platelets, 2015; 26(2): 154–163
© 2015 Informa UK Ltd. DOI: 10.3109/09537104.2014.898178
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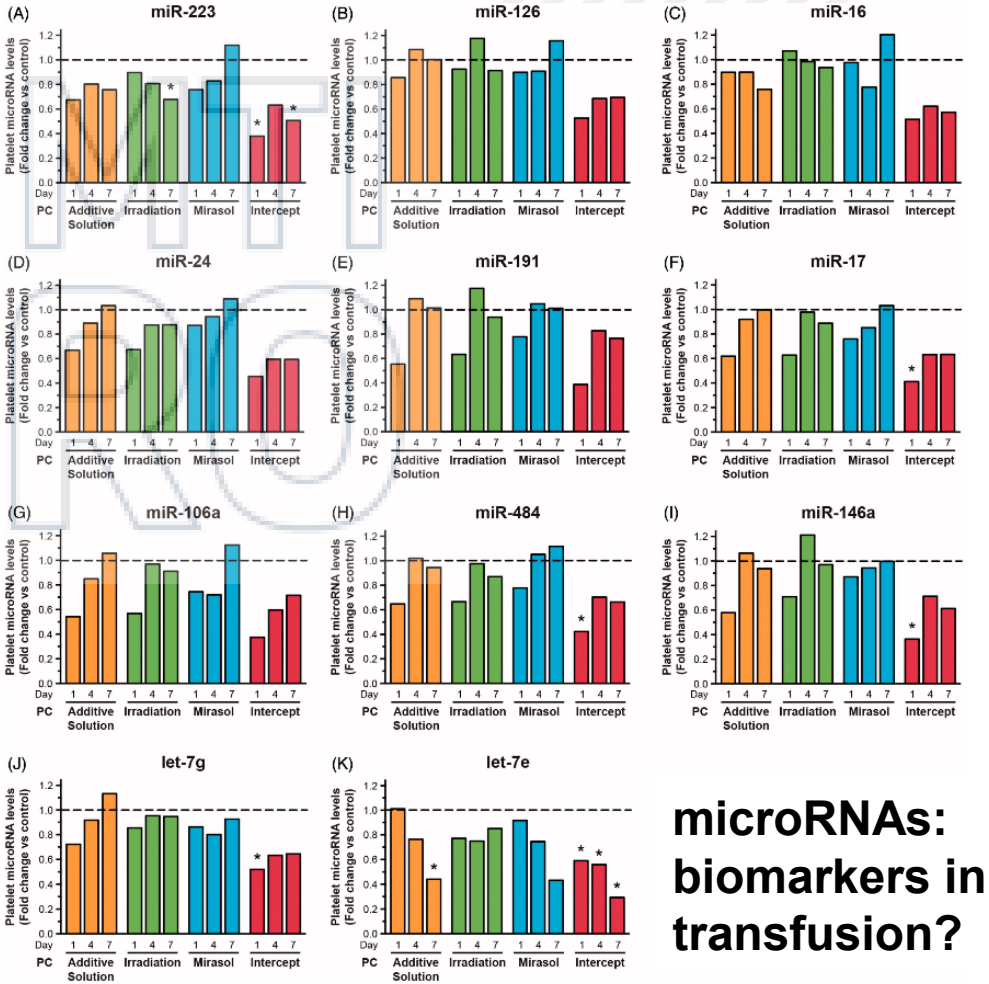
ORIGINAL ARTICLE

## Effects of pathogen reduction systems on platelet microRNAs, mRNAs, activation, and function

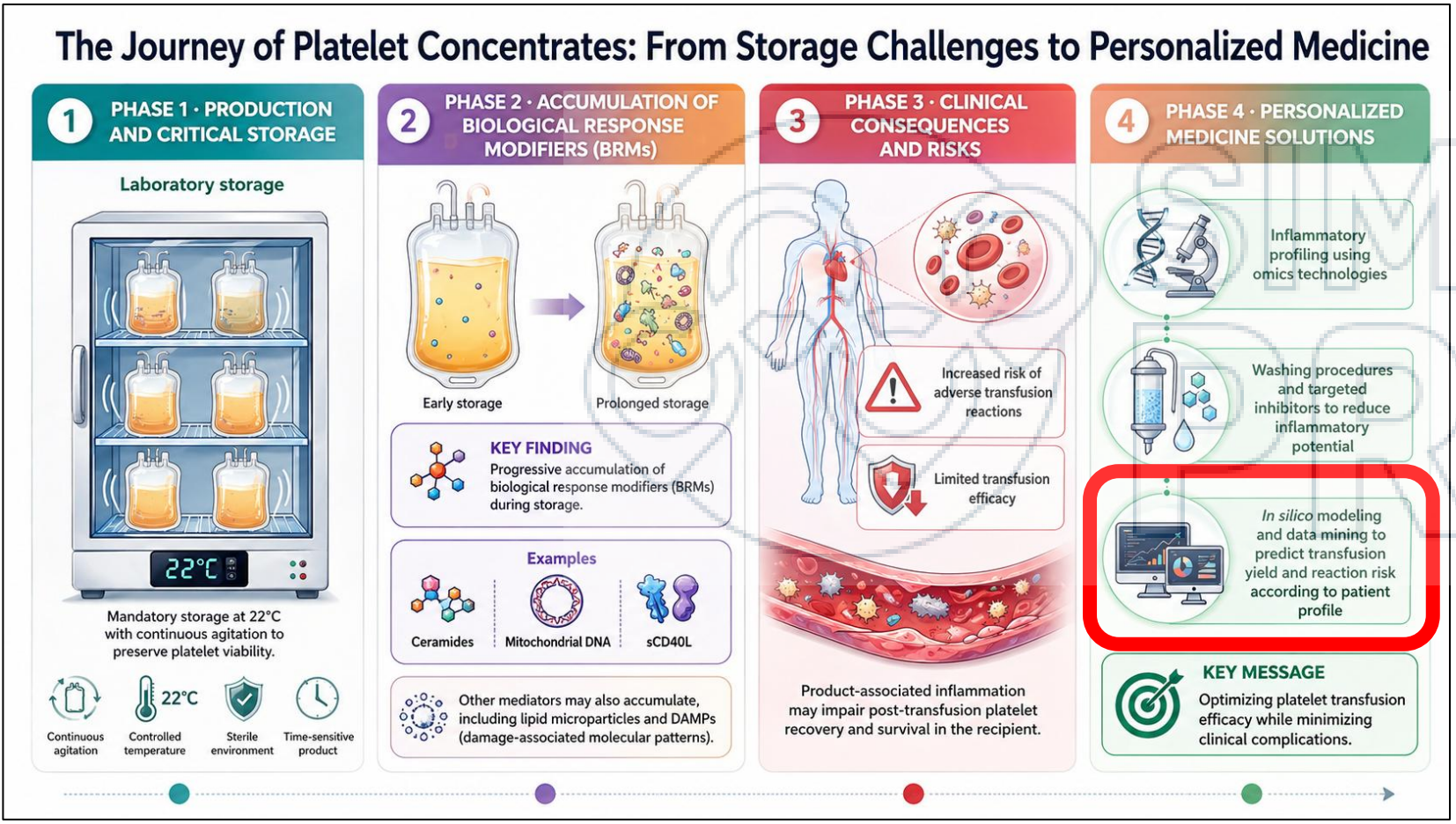
Abdimajid Osman[1], Walter E. Hitzler[2], Claudius U. Meyer[3], Patricia Landry[4,5], Aurélie Corduan[4,5], Benoit Laffont[4,5], Eric Boilard[4,5], Peter Hellstern[6], Eleftherios C. Vamvakas[7], & Patrick Provost[4,5]



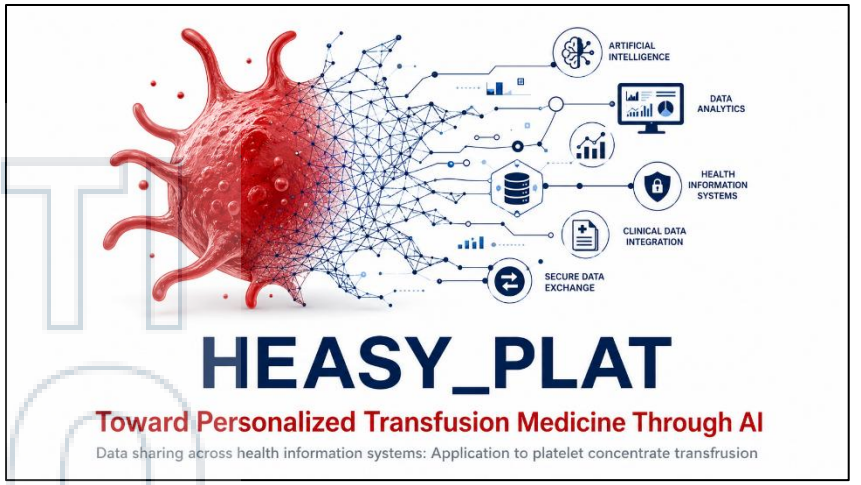

- **microRNAs are small non-coding RNAs that regulate gene expression.**
- **Platelets release microRNAs that influence platelet reactivity.**
- **MicroRNAs could become biomarkers to guide personalised transfusion.**

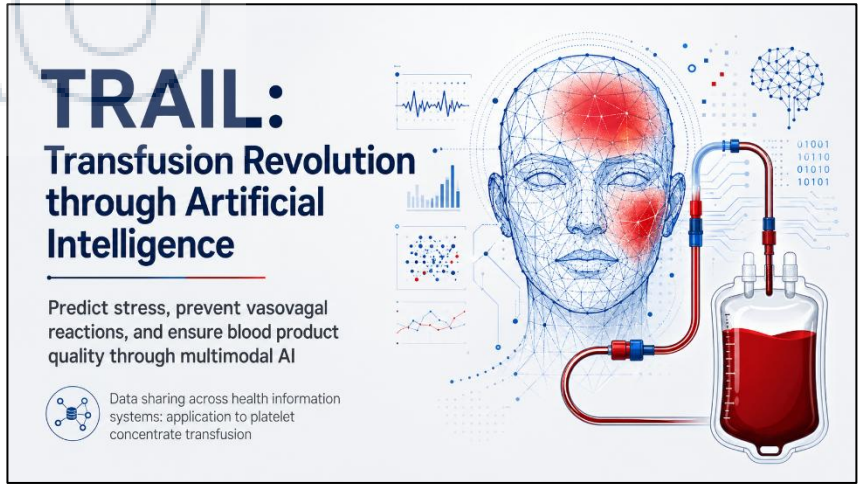
**microRNAs: biomarkers in transfusion?**

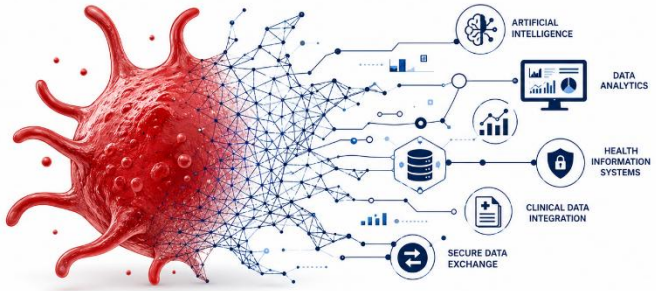
- **Regulatory QC is essential for conformity and safety, but it is a “minimum vital standard”.**
- **Innovative parameters of blood components, especially inflammatory parameters, represent future biomarkers in transfusion.**
- **However, they are not sufficient on their own to predict clinical performance.**




*Adapted from Fabrice Cognasse et al., Blood Transfusion, 2022 (PMID: 35302482).*



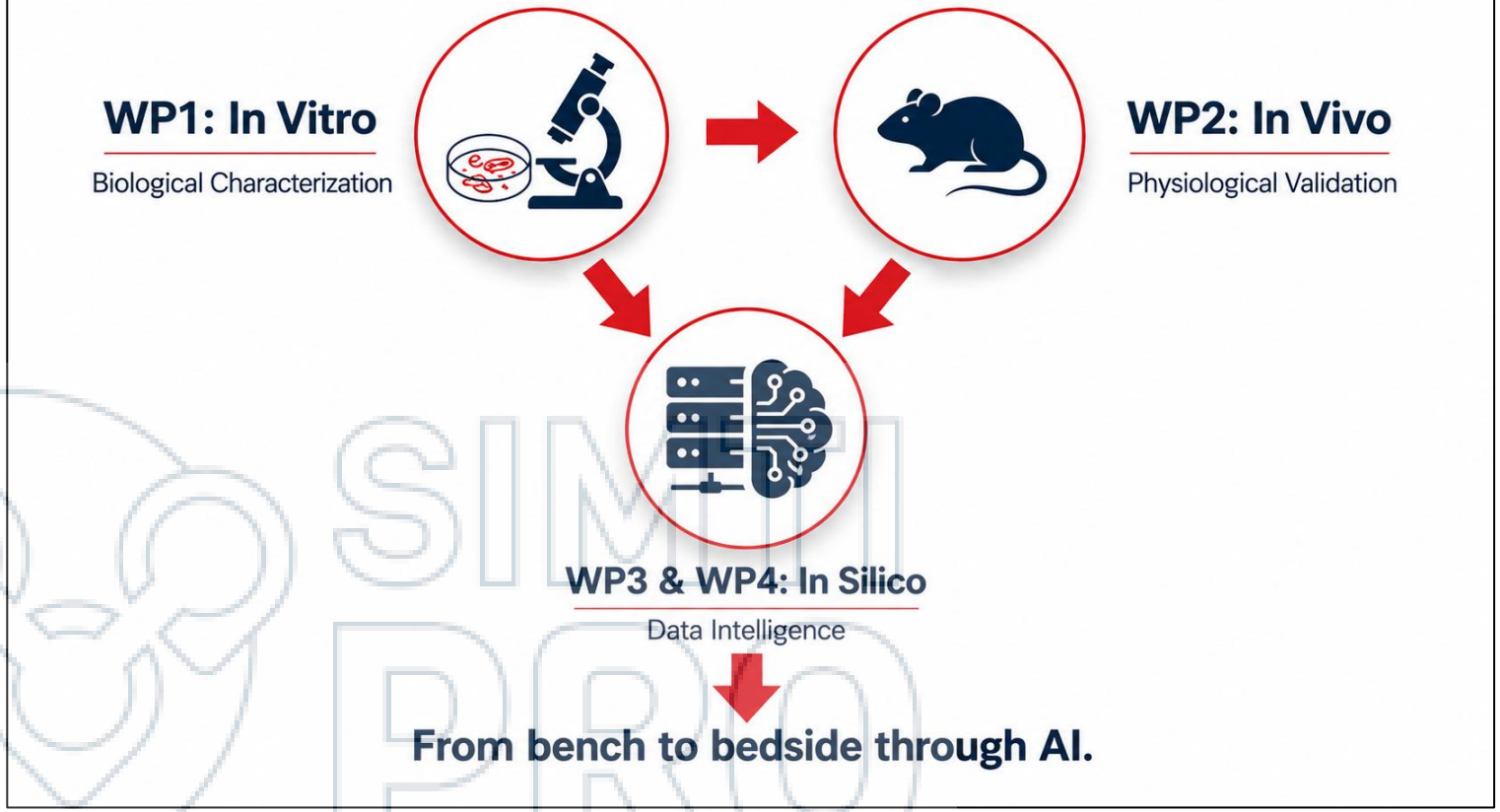






# HEASY_PLAT

## Toward Personalized Transfusion Medicine Through AI

Data sharing across health information systems: Application to platelet concentrate transfusion



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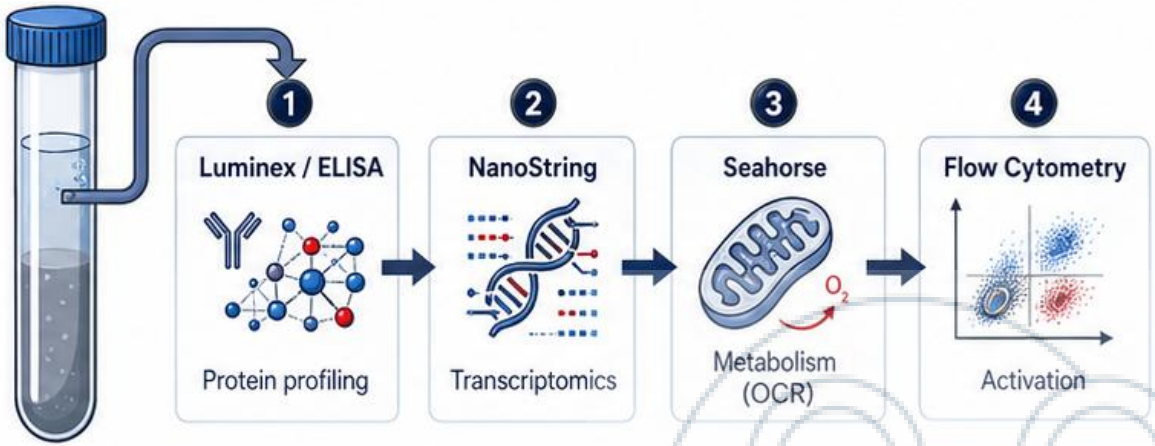
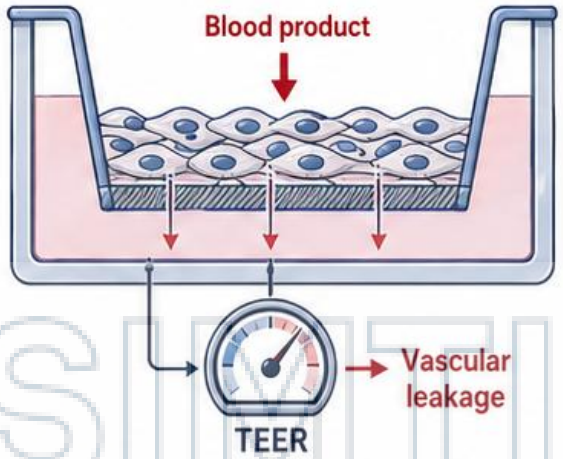
## In Vitro Approach (1/2): Molecular Profiling

*Supernatant analysis: what are we really transfusing?*

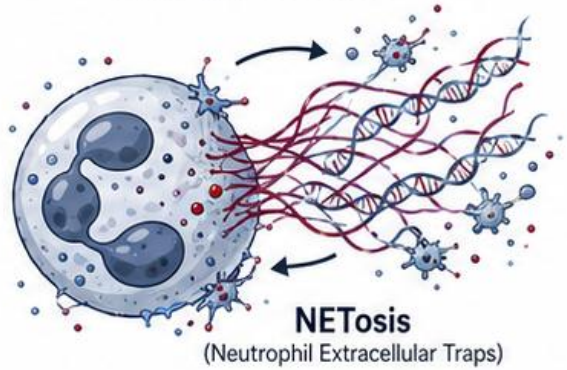



## In Vitro Approach (2/2): Cellular and Vascular Impact

### Endothelial Barrier Model (HUVEC)




### Neutrophil Activation



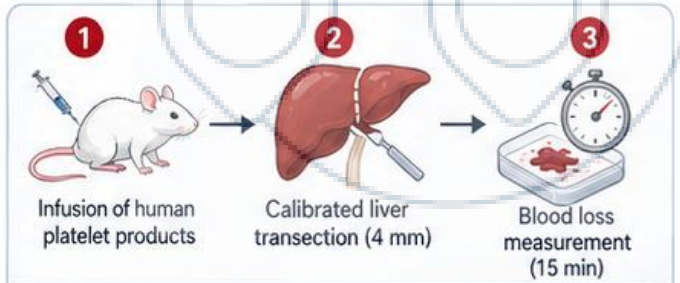

Platelet–neutrophil interaction & **thrombotic risk**

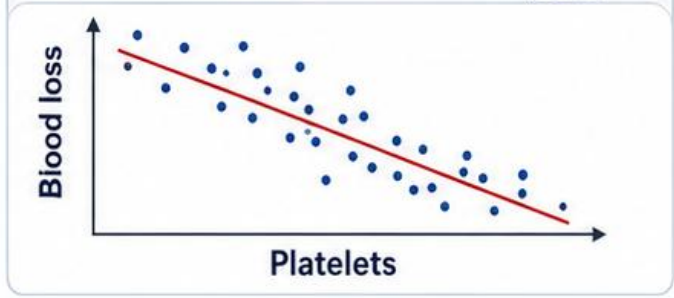
## WP2: In Vivo Approach — Physiological Validation

**Objective:**
Validate the hemostatic and thrombotic impact of inflammation.

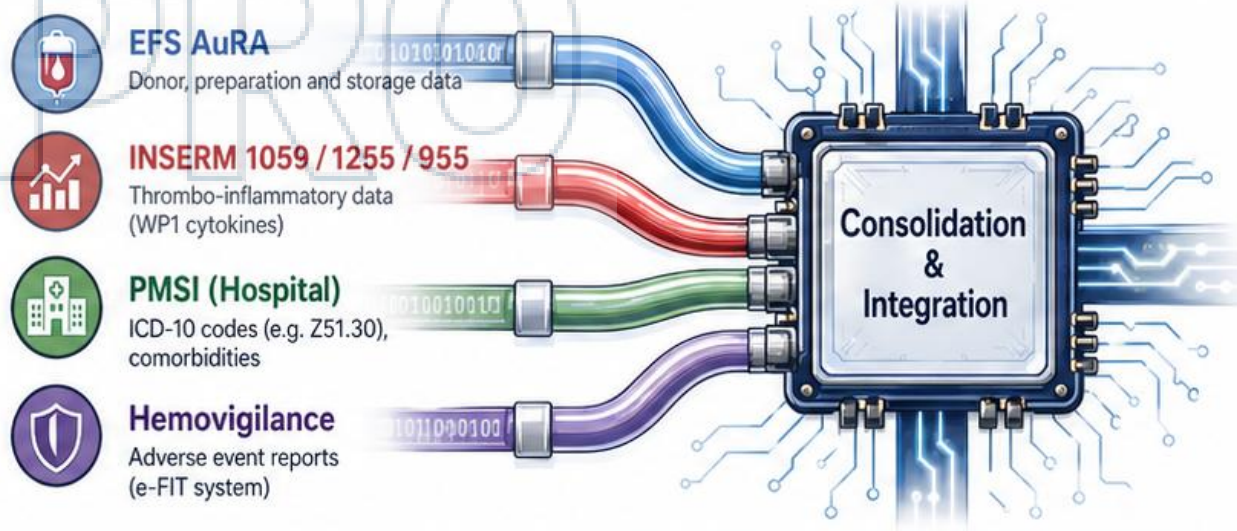
**Model:**
- Humanized mouse (NOD/SCID)
- Scenario: massive hemorrhage (liver transection)

**Key question:**
Does the inflammatory profile identified in WP1 *affect the ability to stop bleeding?*




## WP3: Data Interoperability — Breaking Down Silos



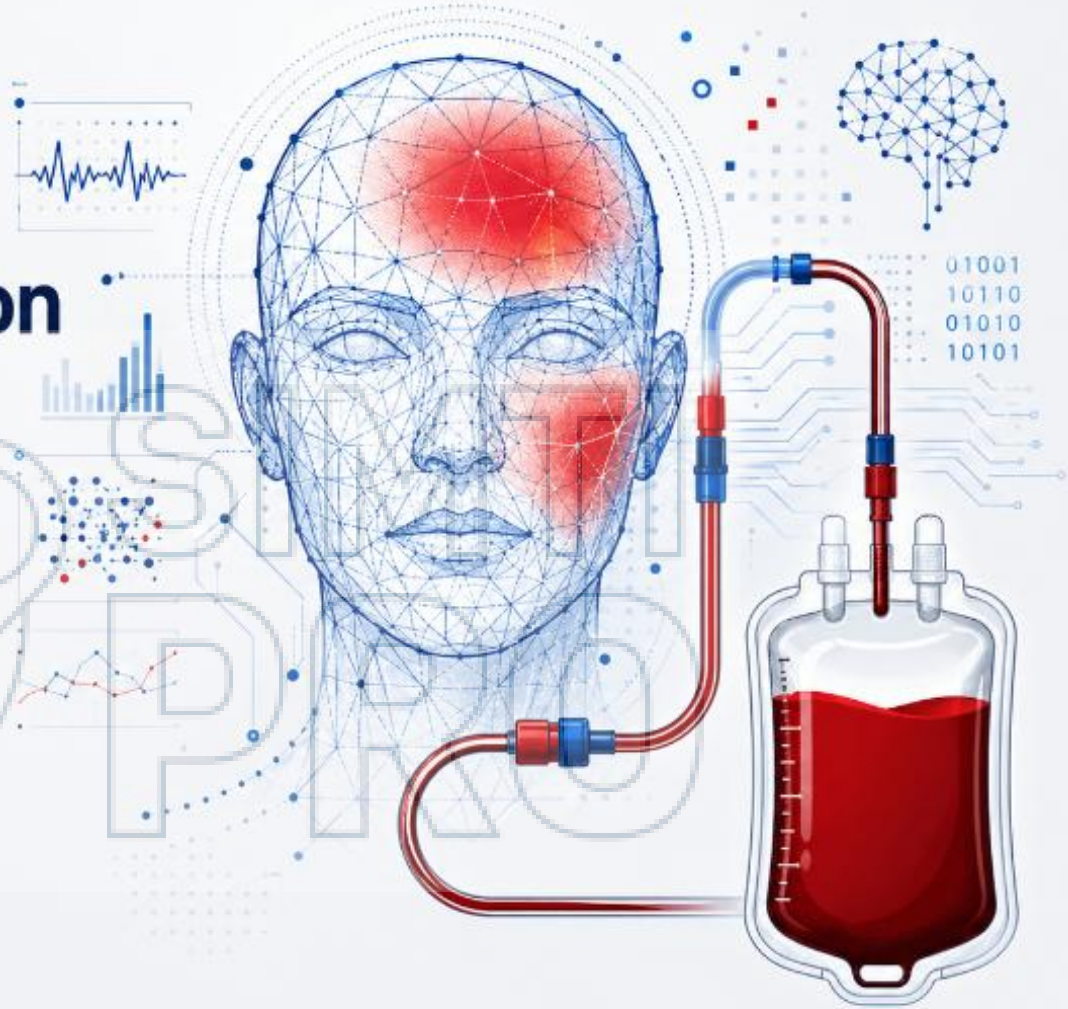

- **Challenge:** linking heterogeneous databases that currently do not communicate.

# TRAIL:

## Transfusion Revolution through Artificial Intelligence

Predict stress, prevent vasovagal reactions, and ensure blood product quality through multimodal AI

Data sharing across health information systems: application to platelet concentrate transfusion

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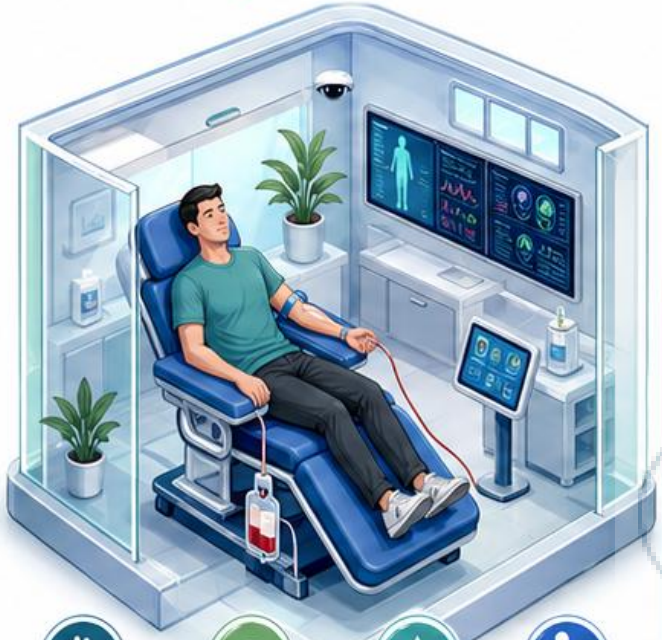
# TRAIL Project: Revolutionizing Blood Transfusion Through Artificial Intelligence

## 1 The Multimodal Donor Journey and Data Collection



Welcome → Interview → Donation → Recovery

### A "Living Lab" to simulate donation

A controlled environment reproduces each step of blood donation to capture standardized, high-resolution data.

## 2 Physiological and psychological data capture

Thermal imaging, facial expression analysis, heart rate monitoring, and cognitive or behavioral measures are integrated to quantify donor stress in real time.

**Thermal imaging**

Detects peripheral vasoconstriction and temperature variations.

**Facial expression analysis**

Measures micro-expressions and affective state.

**Heart rate monitoring**

Tracks heart rate and heart rate variability.

**Cognitive & behavioral assessment**

Evaluates attention, reaction time, and reported stress.

## 3 AI analysis and biological impact

Machine learning integrates multimodal signals to identify stress patterns and relate them to biological alterations in blood products.

Signal integration | Pattern recognition | Biological impact

## 4 Association between stress and inflammatory biomarkers in donors

**Linking stress to biomarkers**

Stress modulates inflammatory mediators such as RANTES and sCD40L, which may influence the quality of labile blood products.

| | Family stress | Donation-related stress | General stress |
|---|---|---|---|
| RANTES | ↑ | ↑↑ | ↑ |
| sCD40L | – | ↑ | – |
| Cortisol | ↑ | ↑ | ↑ |

**Key observations**

- Higher RANTES levels in stressed donors.
- sCD40L increases with donation-related stress.
- Cortisol serves as a reference marker for real-time stress model validation.

## 5 Predictive models and biofeedback

AI-driven models can alert staff and support real-time interventions, including tailored relaxation strategies for donors.

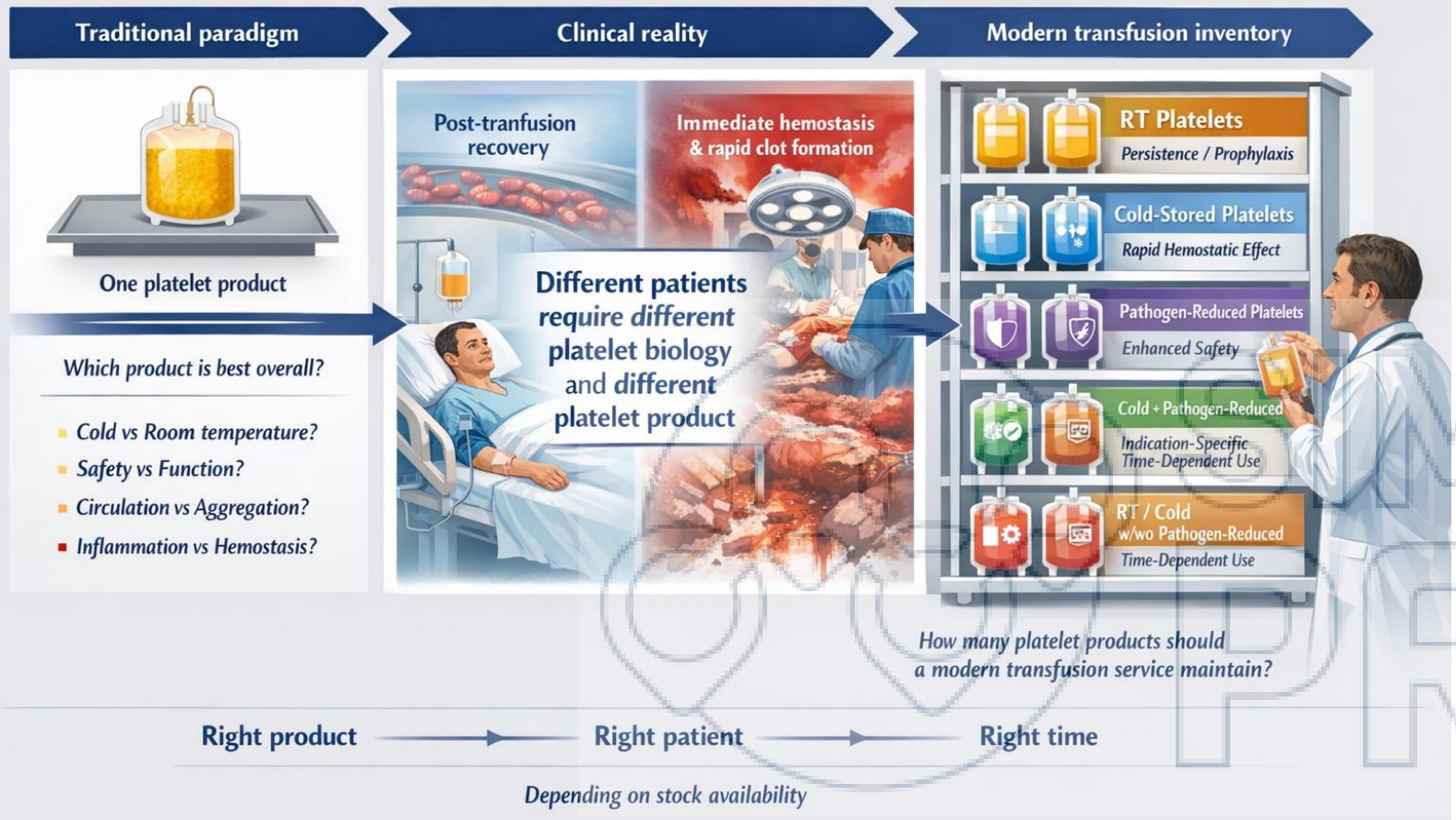
Real-time risk prediction → Staff alerts and interventions → Personalized relaxation and feedback

## 6 Toward personalized transfusion

Improve recipient safety by matching blood products more precisely to the clinical context through data-driven decision support.

Standardized data across controlled conditions | Stress quantification in real time | Evidence-based models to improve blood quality | Better outcomes for donors and recipients

# CONCLUSION

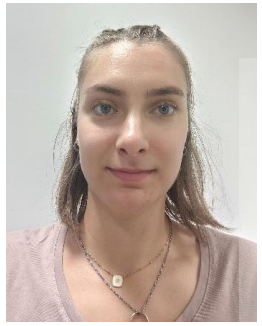
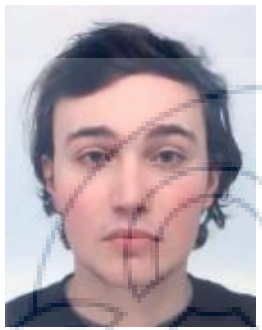
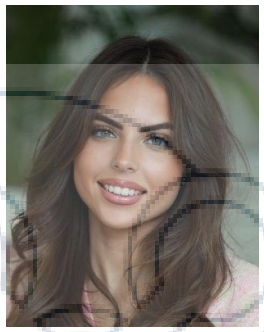



- **That future is no longer theoretical.**
- **The question is no longer what the best platelet product is, but how many platelet products a modern transfusion service should maintain**
- **Paradigm shift:** moving from a single platelet product approach to a diversified, indication-specific platelet inventory.

- **Limits of traditional thinking:** binary trade-offs (cold *vs* room temperature, safety *vs* function, etc.) are insufficient to meet varied clinical needs.
- **Patient-centered requirements:** different conditions demand distinct platelet functions (circulatory persistence *vs* immediate hemostatic action).
- **Modern transfusion strategy:** managing a range of platelet products (room temperature, cold-stored, pathogen-reduced, …) with a focus on optimizing inventory rather than identifying one “best” product.





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