Rapid Hematology Triage

Predictive Algorithms for Mass-Casualty Radiation Events

System Identification

AFRRI

Uniformed Services University

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David L. Bolduc, PhD
Armed Forces Radiobiology Research Institute (AFRRI)
Uniformed Services University (USU)

We dedicate this talk to our late colleague Dr. Miral Dizdaraglu, who’s career in DNA radiation science represented a significant contribution in our field.

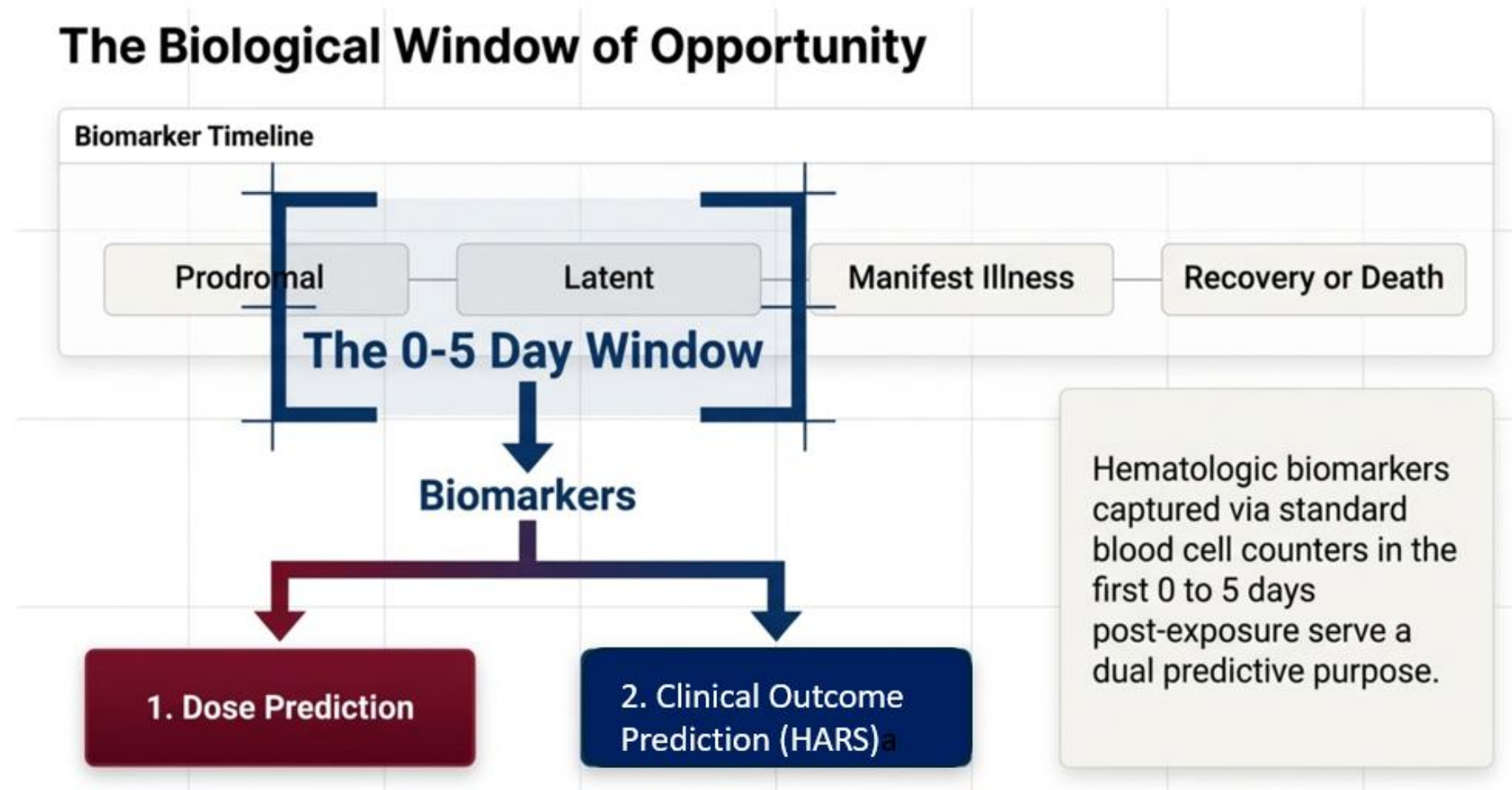
The Real-World Nuclear Threat Demands Mixed-Field Modeling

Most existing triage models rely solely on gamma-ray data. To simulate a realistic mass-casualty radiation accident, triage algorithms must account for mixed-field (neutron and gamma) exposures.

	
Gamma-Only Exposure	**Mixed-Field Exposure (Neutron/Gamma)**

- Event of being exposed to a dangerous radiation dose - nuclear accident or attack
- Triage models designed to respond – such scenarios
- **The standard, idealized baseline for historical radiation modeling – Gamma-only exposure.**

- **A more realistic scenario for a nuclear event would involve a Mixed-Field radiation exposure - an undefined ratio of radiation types.**

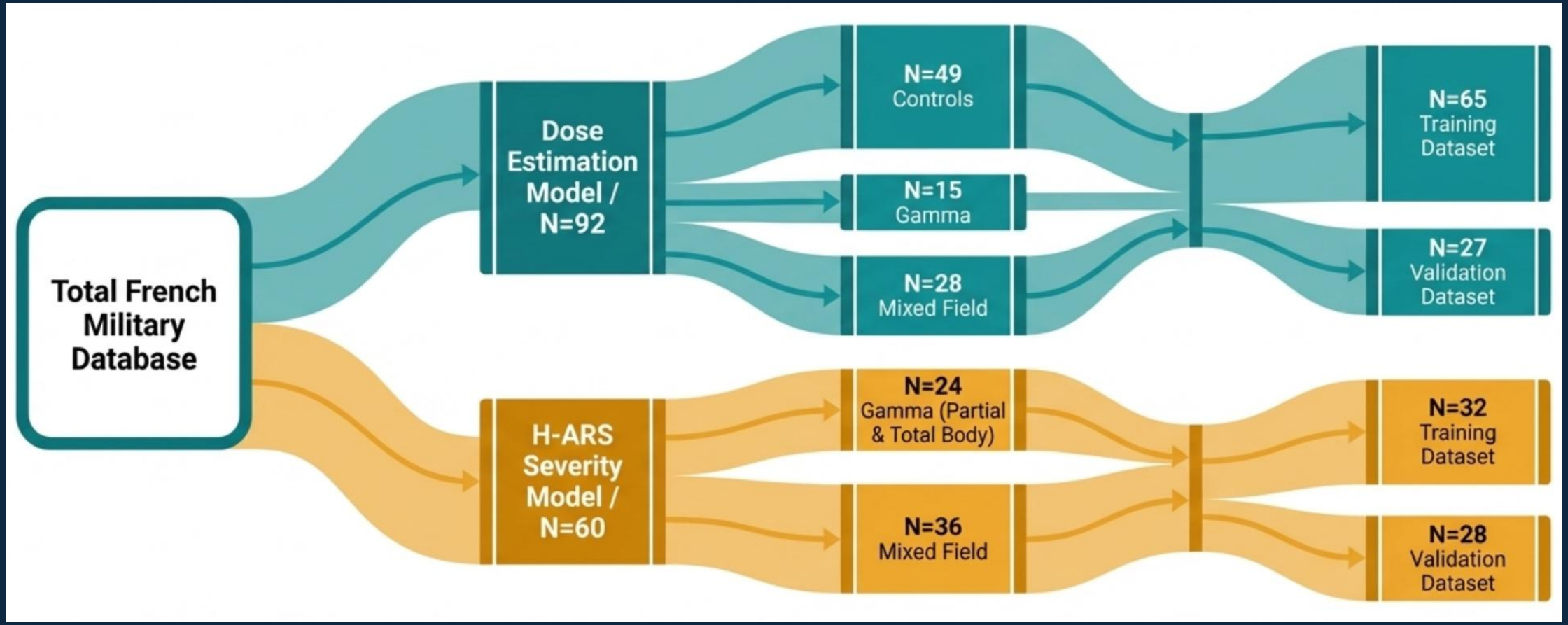


- After receiving adverse rad exposure 0-5 - day window - changes in blood cells
- Assessing rad dose & determining Clinical outcome (HARS)

Hematopoietic Acute Radiation Syndrome (HARS):

- A severe illness occurring after **high-dose**, **whole-body radiation - damages blood-forming stem cells.**
- **Key effects: critical drops in blood cell counts**, leading to **infection**, **hemorrhage**, and **death** within weeks.

French Military Database Used For Modeling



-Collaborated with French Armed Forces Biomedical Institute

-Archived baboon hematology data
-Measured hematological changes
-Gamma and mixed field
-Variety of doses

-Dose Estimation Model 0-8Gy
-HARS Severity Estimation Model
(International METREPOL system's HARS clinical triage categories)

-Medical Treatment Protocols for Radiation Accident Victims

-Strategy: 2 models - complement
-Although knowing physical dose is useful.

-Accurate clinical decision-making requires knowing biological severity of the injury.

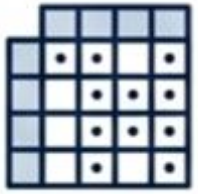
Process for Model Development and Predictive Algorithms for Radiation Dose and HARS Severity

Collection

Days 0-5
Blood Draw.

Standard blood cell counter.

Structuring



Data Matrix Compilation.

Split into Training & Validation.

Selection

Stepwise Analysis.

AI Down-selecting relevant non-colinear biomarker combinations.

Generation

AI Model (MV or BV) Creation.
Creation of Algorithms.

Validation

Tested on Validation Dataset.

Accuracy plotted.

CBC data compiled on to a Data Matrix.

-Training dataset
-Validation dataset

Training dataset correlated in an AI-driven Modeling Software for building models
-Dose Estimation
-HARS Severity.

Models generated Algorithms for predicting Rad Dose and HARS Severity.

Validation set Curve compared with Training set Curve

Dual-Model Architecture: Two Complementary Predictive Tools

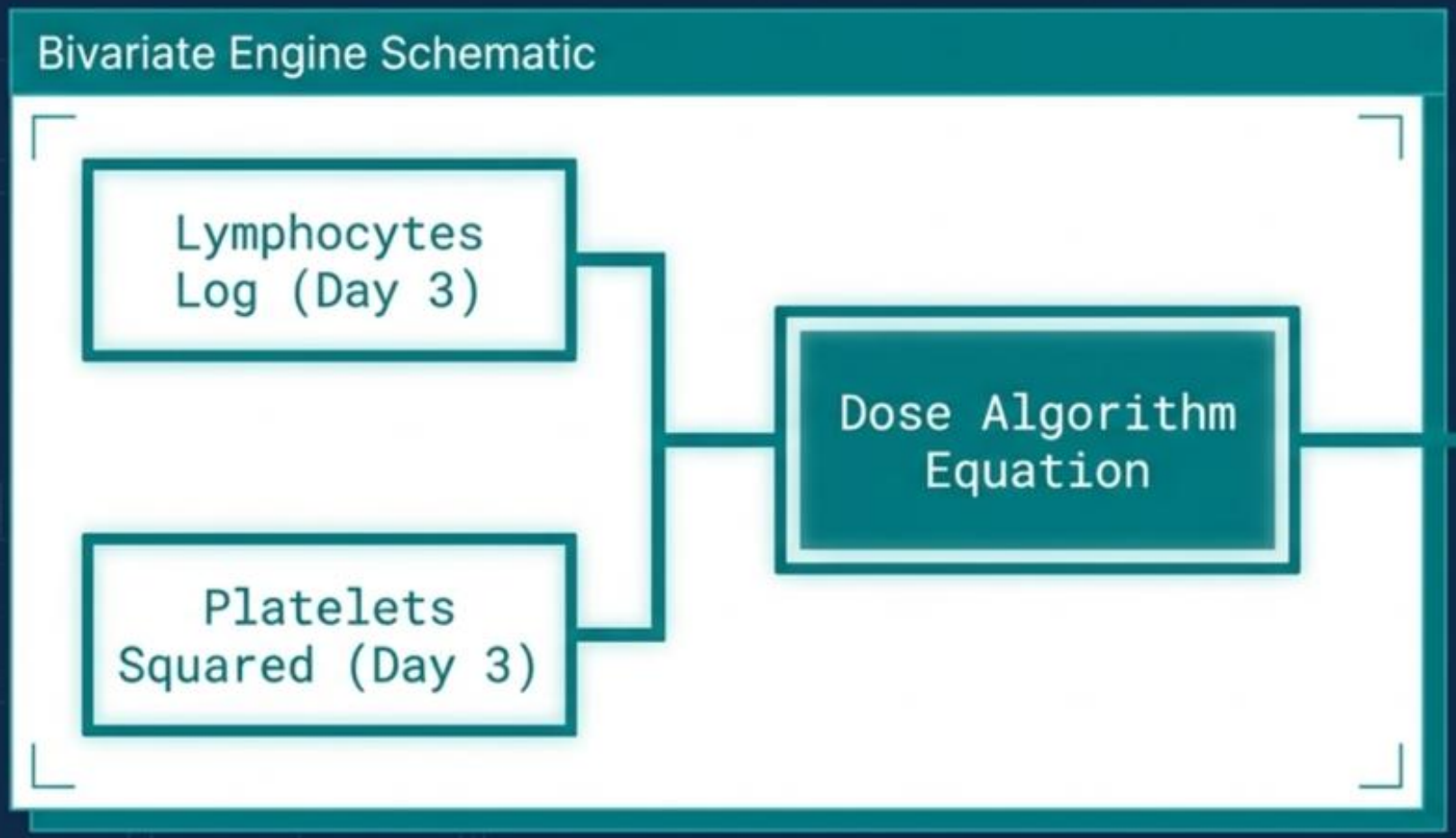
Dose Estimation Model	
Primary Goal	Predict absorbed radiation in Gray (Gy).
Mathematical Approach	Multivariate Regression (Stepwise analysis).
Timeframe / Inputs	Specifically relies on Day 3 hematology measurements.

H-ARS Severity Estimation Model	
Primary Goal	Predict **(Clinical illness) HARS** severity category (METREPOL consensus scoring).
Mathematical Approach	Logistic Regression. (Stepwise analysis).
Timeframe / Inputs	Utilizes the broader 0-5 day hematology window.

Both models utilize standard blood cell counter data, making them highly operational in field or mass-casualty settings.

Dose Estimation Model: The Day-3 Biomarker Signature

The **AI software identified** significant **non-collinear variables** that **directly correlated** with **radiation dose**.



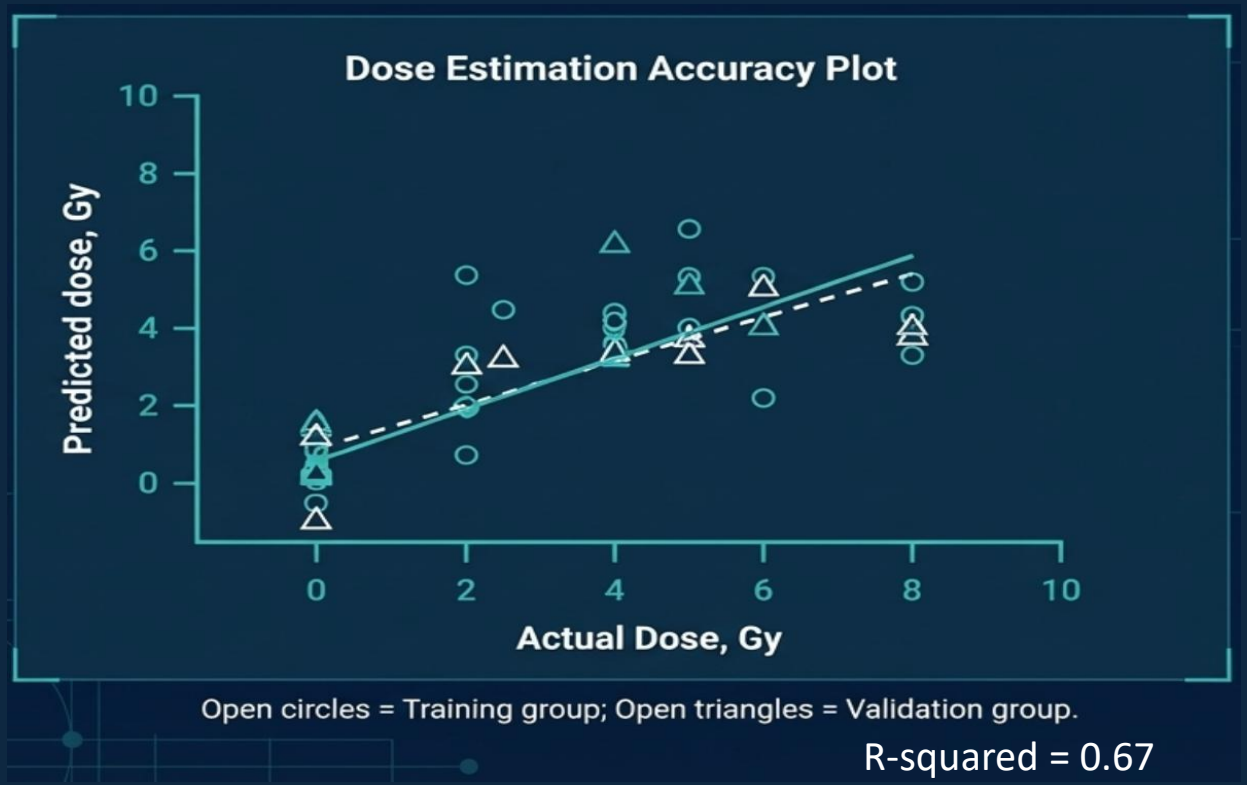
Variables Rejected by AI Selection:

- Lymphocytes Log Day 1
- Lymphocytes Log Day 2
- Neutrophils Log Day 1
- Neutrophils Log Day 2
- Neutrophils Log Day 3
- Platelets Squared Day 1
- Platelets Squared Day 2
- Neutrophil Lymphocyte Ratio Day 1
- Neutrophil Lymphocyte Ratio Day 2
- Neutrophil Lymphocyte Ratio Day 3

The model explicitly rejected early noise, favoring the highly predictive non-linear combination of Day 3 Lymphocyte (Log) and Platelet (Squared) values.

Validation Proves High Reliability for Dose Prediction

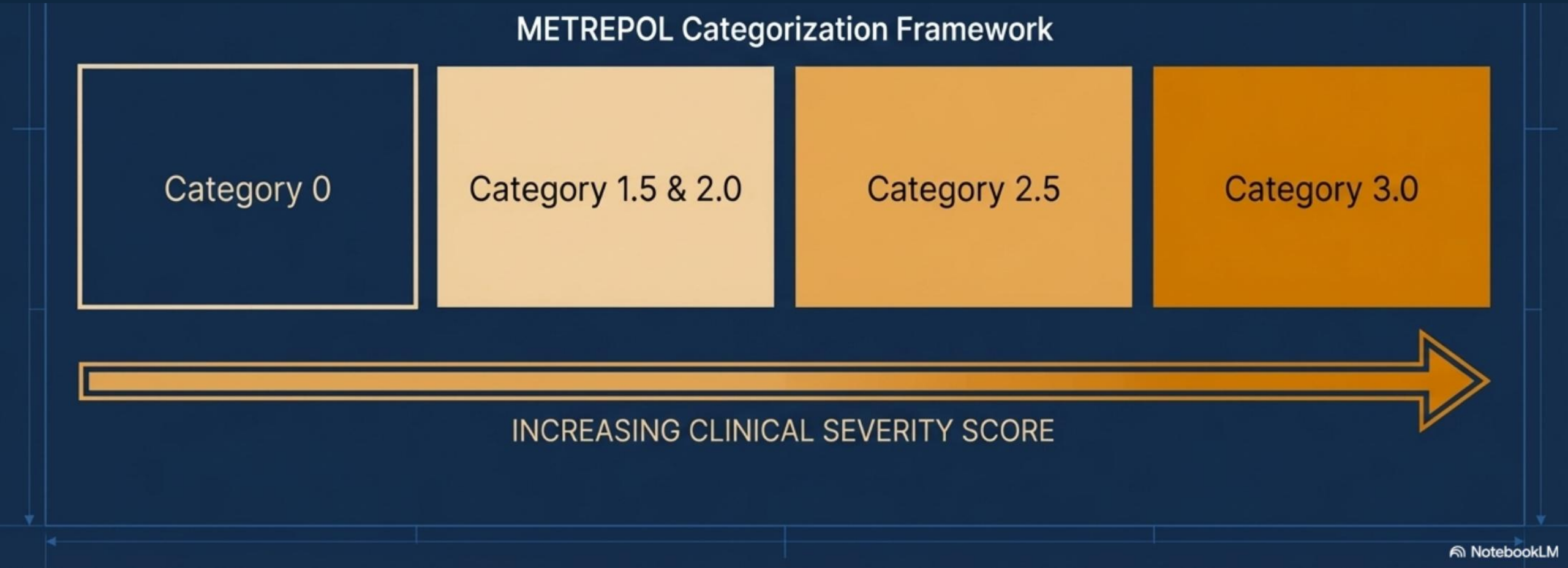
Prediction curves from the Training and Validated datasets were virtually identical documenting no significant degradation when applied to novel data. The data was subsequently pooled.



- **Dose prediction results for Training and Validation datasets plotted – compared**
- **Determined that Training and Validation set curves were virtually identical.**
- **The data was then pooled, and a new dose algorithm and accuracy plot was created consisting of 92 animals.**

HARS Severity Estimation: Categorial Triage

This bivariate model utilizes **Lymphocytes** and **Platelets (Log)** measured across a 0-5 day window to predict consensus severity.



Near Perfect Classification for HARS Severity

Logistic regression fit demonstrates **greater accuracy** in **predicting** HARS severity, with **greater injury severity.**

0 vs. 1.5 & 2.0 H-ARS	0 vs. 2.5 H-ARS	0 vs. 3.0 H-ARS
93.37%	96.57%	99.28%
Correctly Classified	Correctly Classified	Correctly Classified
AUC: 0.974	AUC: 0.990	AUC: 0.995

One Blood Draw. Two Vital Triage Metrics.

By combining both models into a single diagnostic workflow, medical planners can leverage a standard blood cell counter to instantly generate both physical exposure data and clinical triage routing in chaotic mass-casualty environments.

The Rapid Hematology Triage Protocol

Project Summary & Collaborations

Summary Insights

French Baboon database provided a unique resource for developing a more realistic model by consisting of mixed field and gamma only radiation qualities.

Established a functional Dose Estimation model **(0-8.0 Gy)** utilizing day 3 biomarkers.

Developed a highly accurate, bivariate HARS Severity Estimation model (0–5d window) using the consensus METREPOL scoring system.

Credits

Lead Researcher: David L. Bolduc, PhD (AFRRI) / david.bolduc@usuhs.edu

Co-Contributors: William F. Blakely, PhD (AFRRI); Francis Hérodin, PhD (Armed Forces Biomedical Research Institute, France); Lalitha Kurada, PhD (Henry Jackson Foundation).

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Hematology-Based Triage for Mass-Casualty Radiation Events

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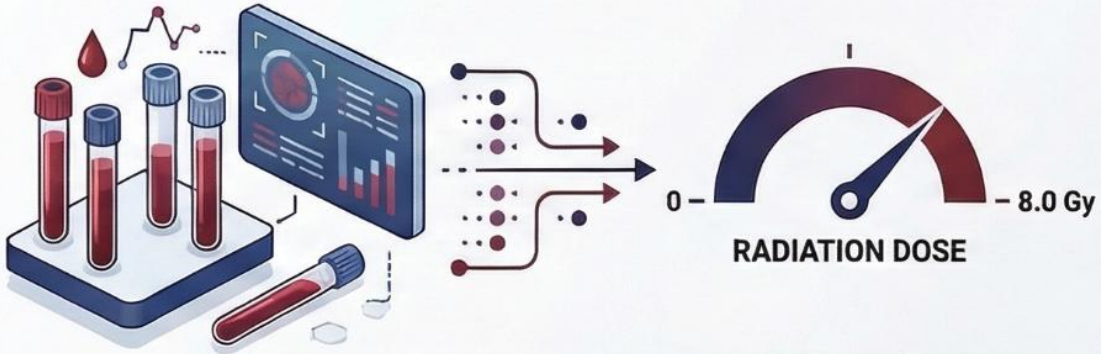
AI-driven algorithms using blood cell biomarkers to rapidly estimate radiation dose and clinical injury severity (H-ARS) for medical triage, based on baboon hematology datasets.

DOSE ESTIMATION

Dose Estimation

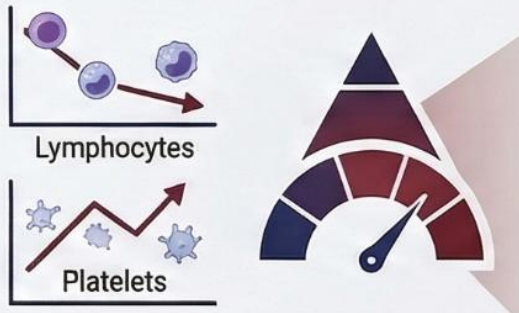
Uses Day 3 lymphocyte and platelet counts to predict exposure up to 8.0 Gy.



HARS SEVERITY SCORING

HARS Severity Scoring

Categorizes injury levels using the METREPOL system based on hematologic biomarker trends.



HARS Severity Estimation Model Accuracy

- Level 3 (Severe) — Highest Accuracy — 99.28% — AUC: 0.995
- Level 2.5 (Significant) — 96.57% — AUC: 0.990
- Level 2 (Mild/Moderate) — 98.37% — AUC: 0.974

MODEL PERFORMANCE & ACCURACY

Biomarker Selection

Models prioritize lymphocyte depletion and platelet squared/log transformations for maximum predictive power.

99.28%
Classification Accuracy

The severity model achieved near-perfect accuracy In predicting the highest injury categories.

High Diagnostic Reliability

ROC curve analysis shows AUC values between 0.974 and 0.995 across all models.

Field Deployment

These algorithms are designed for integration into mobile triage tools like the H-Module.