A PROBABILISTIC MODEL FOR FORECASTING LETHAL OUTCOMES IN COMBINED ACETIC ACID AND ETHANOL INTOXICATION USING HEMOLYTIC BIOMARKERS

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Abstract: *Acute poisonings represent a significant portion of violent deaths in forensic practice, with acetic acid intoxications being particularly prevalent due to its widespread household use. A critical diagnostic and prognostic challenge arises in cases where acetic acid ingestion is complicated by concurrent alcohol intoxication, a combination observed in a majority of clinical and forensic cases. The absence of standardized, quantitative parameters for assessing injury severity and mortality risk in such combined poisonings necessitates the development of objective biomarkers and robust statistical models. This study posits that intravascular hemolysis, a direct consequence of systemic acidemia and corrosive tissue damage, serves as a quantifiable and pathophysiologically grounded criterion for this purpose.*

Keywords: *acetic acid intoxication, ethanol co-ingestion, intravascular hemolysis, probit model, mortality risk prediction, forensic toxicology, automated diagnostics.*

Materials and Methods: The study integrated both retrospective and prospective data from clinical and autopsy sources, encompassing 140 confirmed cases of acute acetic acid poisoning. A subgroup of 60 patients with well-documented outcomes was selected for detailed toxicometric analysis. The core methodological approach involved the precise measurement of plasma-free hemoglobin concentration, which was correlated with the extent of gastrointestinal

tract chemical burns and systemic acidosis. The relationship between the free hemoglobin concentration (dose) and the probability of a lethal outcome (effect) was modeled using probit analysis. This statistical technique allowed for the calculation of lethal dose (LD) thresholds, including LD50, under different intoxication scenarios: isolated acetic acid poisoning, and combined poisoning with moderate (0.5–1.5‰) or severe (>2.5‰) alcohol intoxication. To translate the model into a practical diagnostic tool, the machine learning-based software application "HemoRiskAnalyzer" was developed for the automated determination of hemolysis and risk stratification.

Results: The investigation confirmed that the level of free hemoglobin is a pivotal and measurable indicator of the severity of chemical trauma. A strong positive correlation was established between rising free hemoglobin levels, the extent of visceral damage, and a decreasing blood pH. The probit-modeled dose-response curves revealed a significant modulation of acetic acid toxicity by ethanol. In cases of moderate alcohol co-intoxication, a protective effect was observed, evidenced by a substantial increase in the LD50 of free hemoglobin to 21.8 mg/ml, compared to 13.8 mg/ml in isolated acetic acid poisoning. Conversely, severe alcohol intoxication acted synergistically, drastically reducing the LD50 to 6.83 mg/ml, indicating a marked potentiation of toxicity. The predictive accuracy of the developed probit model was validated by Receiver Operating Characteristic (ROC) curve analysis, which yielded an Area Under the Curve (AUC) of 0.892 (95% CI: 0.865–0.918), confirming its high diagnostic precision. The "HemoRiskAnalyzer" software successfully operationalized these findings, providing a platform for rapid, automated analysis and visual risk reporting.

Conclusion: This study establishes intravascular hemolysis, quantified by plasma-free hemoglobin concentration, as a fundamental and objective biomarker for forensic and clinical assessment in combined acetic acid and alcohol poisoning. The application of probit analysis enables a sophisticated, quantitative risk assessment of mortality, moving beyond qualitative estimates. The divergent effects of alcohol—protective at moderate levels and synergistic at severe levels—highlight

the critical importance of accounting for this co-factor. The integration of these principles into the "HemoRiskAnalyzer" software represents a significant advancement towards standardizing forensic diagnostics and enhancing prognostic decision-making in clinical toxicology. Future research directions should focus on the external validation of this model in diverse populations and the integration of hemolytic data with other omics biomarkers for a more comprehensive pathophysiological understanding.

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