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Commentary

Artificial Intelligence and Predictive Models in Clinical Toxicology Assessment

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ABOVE THE STUDY

Artificial Intelligence (AI) and predictive modeling are rapidly transforming clinical toxicology by improving the speed, accuracy, and efficiency of poisoning diagnosis and management. Toxicology is inherently complex due to the wide variety of toxins, evolving drug formulations, variable patient responses, and often incomplete exposure histories. In this context, AI-driven systems and machine learning–based predictive models offer powerful tools to support clinicians in emergency and critical care settings.

One of the most important applications of AI in clinical toxicology is early risk prediction. Machine learning algorithms can analyze large datasets, including patient demographics, vital signs, laboratory values, electrocardiograms, and toxicology reports, to identify patterns associated with severe poisoning outcomes. These predictive systems can assist clinicians in stratifying patients based on risk, enabling early intervention for those most likely to deteriorate. For example, AI models can predict the likelihood of respiratory failure in opioid overdose or the risk of cardiotoxicity in tricyclic antidepressant poisoning.

AI also plays a significant role in toxic exposure identification. Traditional toxicology screening methods may be time-consuming or limited in detecting emerging substances. In contrast, AI-based systems can integrate clinical data with chemical databases and pharmacological profiles to suggest potential toxic agents based on symptom patterns. This is particularly valuable in cases involving novel psychoactive substances or poly-drug overdoses, where standard laboratory tests may be insufficient.

Predictive models are increasingly being used to improve decision-making in emergency toxicology care. Clinical Decision Support Systems (CDSS) powered by AI can recommend diagnostic tests, suggest antidotal therapies, and guide decontamination or supportive care strategies. These systems help reduce diagnostic uncertainty and improve adherence to evidence-based protocols. In addition, AI tools can assist in determining the appropriate level of care, such as intensive care unit admission versus general ward observation.

Another emerging application is the use of AI in pharmacovigilance and toxicovigilance. By analyzing electronic health records, adverse drug reaction databases, and even social media data, AI systems can detect early signals of drug toxicity or emerging poisoning trends. This real-time surveillance capability enhances public health response and supports regulatory actions to prevent widespread toxic exposures.

In laboratory toxicology, AI is being integrated with advanced analytical techniques such as mass spectrometry and chromatography. Machine learning algorithms can interpret complex spectral data, improving the speed and accuracy of toxin identification. This reduces human error and enhances the detection of rare or unknown compounds, contributing to more precise toxicological diagnosis.

Despite its promising potential, the use of AI in clinical toxicology faces several challenges. Data quality and availability remain major limitations, as predictive models require large, well-annotated datasets for training. Variability in clinical documentation, differences in laboratory standards, and underreporting of poisoning cases can affect model performance. Additionally, concerns related to patient privacy, data security, and ethical use of AI must be carefully addressed.

Another important limitation is the lack of external validation in many AI models. Systems developed in controlled research environments may not always perform effectively in real-world clinical settings. Therefore, continuous validation, updating of algorithms, and integration with clinician expertise are essential for safe and effective implementation.

In conclusion, artificial intelligence and predictive models are emerging as powerful tools in clinical toxicology assessment. They enhance early diagnosis, improve risk stratification, support clinical decision-making, and strengthen toxicovigilance systems. While challenges remain in terms of validation, data quality, and ethical considerations, ongoing technological advancements are expected to significantly improve the role of AI in toxicology practice. The integration of AI with traditional clinical expertise has the potential to redefine modern toxicology and improve patient outcomes in poisoning management.

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