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# THE ROLE OF ARTIFICIAL INTELLIGENCE IN *AGAD TANTRA* (AYURVEDIC TOXICOLOGY)- A NARRATIVE REVIEW

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## ABSTRACT

*Agad Tantra*, the Ayurvedic branch of toxicology, is highly relevant in present-day India where toxicological emergencies such as snakebite, pesticide poisoning, adulterated botanicals, and drug toxicities remain major challenges. The rapid evolution of artificial intelligence (AI) in biomedical science offers new opportunities to complement classical Ayurvedic diagnostics and modern toxicological methods. This narrative review was conducted using indexed biomedical literature (2019–2025) and official Indian and international guidelines. Databases including PubMed, Scopus, and OECD portals were searched with keywords such as *"AI AND snakebite identification"*, *"AI AND ECG AND digoxin toxicity"*, *"methanol poisoning AND machine learning"*, and *"QSAR Toolbox AND toxicology."* Findings suggest that AI can support multiple domains of *Agad Tantra*. In clinical care, image-based snake species recognition aids antivenom decisions, AI-assisted ECG flags digoxin cardiotoxicity, and explainable models predict airway needs in methanol poisoning. In laboratories, machine learning accelerates mass spectrometry analysis, while chemometric fingerprints ensure rapid authentication of Ayurvedic botanicals. At the policy and educational level, OECD QSAR frameworks provide transparent, auditable workflows for preliminary assessment of *kṛtrima viṣa* (artificial poisons). AI, when employed as an *upakaraṇa* (adjunct), has the potential to improve speed, accuracy, and consistency in toxicological practice. However, safe adoption requires adherence to ICMR ethical guidelines, the Digital Personal Data Protection Act, and ABDM standards. With appropriate

validation and governance, AI can strengthen *Agad Tantra* practice in both district hospitals and Ayurvedic teaching institutions.

**KEYWORDS:** *Agad Tantra*, Artificial Intelligence, Snakebite, Digoxin, Methanol Poisoning, Chemometrics, QSAR, Toxicovigilance.

## INTRODUCTION

*Agad Tantra*, one of the eight major branches of Ayurveda, deals with the identification, diagnosis, and management of poisons (*viṣa*) from animals (*jaṅgama*), plants and minerals (*sthāvara*), and artificial or synthetic sources (*kṛtrima*).[1] Its principles emphasize precise *nidāna* (assessment) and timely intervention, which remain highly relevant in India, where toxicological emergencies are a continuing public health concern.

Snakebite is one of the leading causes of toxicological mortality in rural areas. A nationally representative study estimated nearly 1.2 million snakebite deaths in India between 2000 and 2019, with the majority occurring in resource-limited settings where access to antivenom and expert identification is inadequate.[2] Pesticide poisoning, adulterated herbal drugs, and drug-induced toxicities add to this burden, making innovations in diagnostic and supportive technologies essential.[3]

In recent years, artificial intelligence (AI) has emerged as a practical tool in healthcare, providing opportunities for improved clinical decision-making, laboratory analysis, and surveillance. Computer-vision models have been applied to mobile-phone images for snake species identification, supporting clinicians in choosing the correct antivenom.[4,5] AI-assisted interpretation of electrocardiograms has demonstrated the ability to detect digoxin-induced cardiotoxicity, providing an early warning in toxicology cases.[6] Similarly, explainable AI models for methanol poisoning have shown potential in predicting the need for airway interventions, thereby reducing delays in life-saving management.[7]

Laboratory applications include machine learning for high-resolution mass spectrometry, which accelerates the detection of unknown poisons and adulterants.[8] Chemometric fingerprinting methods such as ATR-FTIR, HPTLC, and LC-MS enable rapid authentication of Ayurvedic botanicals, ensuring quality assurance in teaching pharmacies and hospital dispensaries.[9,10] At a policy and educational level, OECD's QSAR Toolbox provides structured and auditable workflows for early screening of *kṛtrima viṣa*.[11]

For India, safe adoption of AI requires adherence to regulatory safeguards. The Indian Council of Medical Research (ICMR) has issued ethical guidelines for AI use in biomedical research, while the Digital Personal Data Protection (DPDP) Act, 2023, and the Ayushman Bharat Digital Mission (ABDM) provide frameworks for lawful and transparent data sharing.[12,13]

This review aims to highlight the practical applications of AI in *Agad Tantra*, identify its role in clinical and laboratory settings, and propose governance measures tailored to the Indian Ayurvedic context.

## AIM AND OBJECTIVES

### AIM

To explore the role of artificial intelligence (AI) in *Agad Tantra* (Ayurvedic toxicology) and to propose practical applications and governance strategies relevant to the Indian context.

### OBJECTIVES

1. To identify clinical applications of AI in toxicological emergencies such as snakebite, digoxin toxicity, and methanol poisoning.
2. To describe laboratory applications of AI in poison detection, quality assurance, and botanical authentication.
3. To assess the utility of in-silico models such as the OECD QSAR Toolbox for screening of *kṛtrima viṣa* (artificial poisons).
4. To examine the scope of AI in toxicovigilance and poison-centre documentation.
5. To propose governance frameworks integrating ICMR ethical guidelines, the Digital Personal Data Protection Act, and ABDM standards for responsible AI adoption.

## MATERIALS AND METHODS

### STUDY DESIGN

This article is a narrative review, synthesising evidence on the practical applications of artificial intelligence (AI) in *Agad Tantra*. The emphasis was on clinical, laboratory, and governance-related aspects relevant to India.

### SOURCES OF DATA

Electronic databases including PubMed.[14] and Scopus.[15] were searched for indexed biomedical and toxicology-related literature. Additional grey literature and guidelines were

retrieved from authoritative portals such as the Indian Council of Medical Research (ICMR) for AI ethics (16), the Ayushman Bharat Digital Mission (ABDM) portal.[17] and the OECD official portal for QSAR Toolbox resources.[18]

## SEARCH STRATEGY

Keywords used included

- *"AI AND snakebite identification"*
- *"AI AND ECG AND digoxin toxicity"*
- *"methanol poisoning AND machine learning"*
- *"chemometric herbal authentication"*
- *"QSAR Toolbox AND toxicology"*

The time frame for the search was January 2019 to August 2025. Older landmark studies were included where necessary.

## INCLUSION CRITERIA

- Peer-reviewed human studies
- Substantial reviews and meta-analyses
- Official policy or guideline documents
- Analytical method studies linking AI with toxicology

## EXCLUSION CRITERIA

- Non-English publications
- Opinion pieces or editorials without data
- Algorithm-only studies lacking clinical/laboratory application

## DATA SYNTHESIS

The extracted information was thematically grouped into four categories

1. **Clinical Applications** – bedside diagnostic and decision-support tools.
2. **Laboratory Applications** – analytical toxicology and botanical authentication.
3. **In-silico Toxicology** – computational risk assessment tools.
4. **Toxicovigilance and Governance** – registries, documentation, and regulatory frameworks.

## REVIEW OF LITERATURE

### 1. Clinical Applications in *Visha Chikitsa*

Snakebite envenomation remains a major challenge in India. AI-based computer-vision models trained on global image datasets have demonstrated the ability to identify snake species from mobile-phone photographs, assisting clinicians in selecting the correct antivenom.[19,20] A scoping review confirmed that such models can serve as clinician-support tools in regions where expert identifiers are unavailable.[21]

AI has also been applied to electrocardiograms (ECG). Deep-learning models have successfully detected digoxin-induced cardiotoxicity from routine ECGs, highlighting its role as an adjunct diagnostic aid in toxicological practice.[22] In toxic alcohol exposures, explainable AI models have shown utility in predicting the need for early intubation in methanol poisoning, thereby supporting timely airway management and reducing mortality risk.[23]

### 2. Laboratory Applications in *Visha Pariksha*

High-resolution mass spectrometry (HRMS) is an important tool in toxicological investigations. Machine-learning algorithms improve efficiency by automating peak picking, deconvolution, and annotation, which helps in the rapid detection of unknown poisons and adulterants.[24]

Chemometric approaches using ATR-FTIR, HPTLC, and LC-MS fingerprints, when combined with multivariate statistical models, enable authentication of herbal medicines. These methods have been validated in several studies for rapid discrimination of genuine and adulterated botanicals, including *Curcuma* species and multi-tier pipelines for traditional medicines.[25,27]

### 3. In-silico Toxicology for *Kṛtrima Visha*

The OECD QSAR Toolbox provides structured, auditable workflows for early hazard prediction of chemicals. It incorporates features such as applicability domain checks, reliability scoring, and transparent documentation of assumptions, making it suitable for teaching toxicology in Ayurvedic institutions.[28,30] These tools allow preliminary risk assessments before experimental confirmation, saving time and resources.

### 4. Toxicovigilance and Documentation

Toxicovigilance involves structured surveillance of poison cases. The U.S. National Poison Data System (NPDS) demonstrates the effectiveness of near real-time case uploads and annual benchmarking, which can serve as a model for Indian practice.[31] Emerging research also highlights the potential of large language models (LLMs) in drafting poison-centre records, thereby reducing documentation burden while maintaining clinical oversight.[32]

## DISCUSSION

The integration of artificial intelligence (AI) into *Agad Tantra* shows considerable promise in addressing pressing toxicological challenges in India. Clinical applications are the most immediately impactful, particularly snakebite recognition, digoxin toxicity detection, and methanol triage. These tools rely on routinely available data such as mobile photographs, ECGs, and bedside parameters, making them feasible even in district hospitals. However, their success depends on proper calibration, clinician oversight, and validation in Indian settings to reduce errors caused by device variability and population differences.[33]

Laboratory applications further highlight the role of AI in toxicology. Machine learning has improved the efficiency of high-resolution mass spectrometry, enabling faster detection of unknown toxins and adulterants.[24] Chemometric fingerprinting has been validated for several botanicals, providing a rapid and cost-effective approach to quality assurance.[25.27] Despite these advantages, challenges remain in terms of infrastructure costs and technical expertise, which may limit widespread adoption in smaller Ayurvedic colleges.[34]

In-silico toxicology tools such as the OECD QSAR Toolbox bring transparency and reproducibility to hazard screening.[28,30] These frameworks provide structured reasoning that can be incorporated into Ayurvedic toxicology teaching. However, adaptation is required for complex polyherbal formulations commonly used in Ayurveda, which do not easily fit into conventional computational models.[35]

Toxicovigilance represents another emerging field where AI can contribute significantly. International examples such as the NPDS show how real-time registries can strengthen surveillance.[31] Incorporating large language models (LLMs) for documentation may reduce the workload on clinicians, but issues related to privacy, bias, and accountability need careful attention.[32] In India, the development of ABDM-linked toxicology registries could bridge this gap, but implementation must be stepwise and ethically monitored.

A key theme is that AI should function as an *upakaraṇa* (adjunct) to clinical and toxicological judgment rather than a replacement. Governance frameworks—including the ICMR ethical guidelines, DPDP Act, and ABDM digital rails—are essential to ensure safety, accountability, and patient trust.[16,1736] Without robust governance, risks such as over-reliance, data misuse, and inequity may overshadow the benefits.

## CONCLUSION

Artificial intelligence (AI) can serve as an effective *upakaraṇa* (adjunct) in *Agad Tantra*, improving speed and accuracy in toxicological care. Clinical tools like snake-photo recognition.[19,21] AI-ECG for digoxin toxicity.[22] and methanol triage models.[23] show immediate relevance, while laboratory methods such as mass spectrometry with machine learning.[24] and chemometric authentication.[25,27] enhance safety. In-silico QSAR frameworks.[28,30] and AI-assisted toxicovigilance.[31,32] provide structured approaches to risk assessment and surveillance. Safe adoption in India requires strict alignment with ICMR, DPDP, and ABDM governance frameworks.[16,17,36]

## LIMITATIONS

This review is narrative and not a meta-analysis. Evidence is heterogeneous, with few large Indian validations.[37] High-end infrastructure needs and limited Ayurveda-specific AI studies remain major constraints .[34,38]

## FUTURE SCOPE OF STUDY

AI applications in *Agad Tantra* require further validation before large-scale adoption. Multicentric trials for snake-photo recognition are needed to ensure reliability across diverse Indian settings.[39] AI-assisted ECG should be tested through cluster-based studies to confirm its role in early digoxin toxicity detection.[40] Explainable AI models for methanol poisoning demand prospective validation with clinical outcomes such as airway management and mortality.[41] Collaborative ring trials can develop cost-effective chemometric spectral libraries for Ayurvedic botanicals.[42] OECD QSAR frameworks should be adapted for complex polyherbal formulations to strengthen in-silico toxicology.[43] Establishing ABDM-linked toxicovigilance registries, possibly supported by AI-assisted documentation, will improve surveillance.[44] Finally, health-economic studies are essential to assess cost-effectiveness and sustainability of AI integration in district hospitals.[15]

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