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Review Article

Telemedicine in Clinical Toxicology: Applications, Clinical Impact, Challenges, and Future Directions—A Narrative Review

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ABSTRACT

Background: Clinical toxicology depends on rapid access to specialist knowledge, yet medical toxicologists are unevenly distributed and may not be available at every hospital. Telemedicine can extend toxicology expertise across geographic boundaries and may improve triage, treatment decisions, resource utilization, education, and surveillance. This review examines current and emerging applications of telemedicine in clinical toxicology, including individual patient care, poison center and specialist consultation, public health surveillance, digital infrastructure, and emerging technologies.

Methods: A narrative literature review was conducted using PubMed-indexed literature, peer-reviewed clinical toxicology studies, implementation reports, economic evaluations, and authoritative digital-health and interoperability documents. The evidence was synthesized narratively rather than quantitatively.

Results: Tele-toxicology can provide real-time or asynchronous assessment, exposure identification, risk stratification, interpretation of electrocardiograms (ECGs) and laboratory data, antidote guidance, disposition decisions, follow-up, and clinician education. Evidence for poison-center and specialist toxicology consultation is more developed than evidence demonstrating an independent benefit of a specific telemedicine modality. Observational and service-evaluation studies associate poison-center involvement with fewer potentially unnecessary emergency-department visits and shorter hospital stays, while recent national digital programs demonstrate feasibility and scalability. Evidence for prospective, comparative, patient-centered outcomes remains limited.

Conclusion: Telemedicine can extend specialist toxicology expertise across geographic and institutional boundaries and may reduce unnecessary healthcare utilization in selected settings. However, the evidence base is heterogeneous and is dominated by observational studies, service evaluations, implementation reports, and economic analyses. Future research should prioritize prospective comparative studies, patient safety outcomes, standardized endpoints, interoperability, cybersecurity, and validation of emerging digital and artificial intelligence tools.

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Introduction

Poisoning is a time-sensitive clinical and public health problem. Patients may present with incomplete exposure histories, uncertain doses, mixed ingestions, unusual toxic agents, or rapidly evolving toxidromes, with or without suicidal intent. Clinical toxicology therefore requires integrating history, examination, electrocardiography, laboratory data, toxicokinetics, and evidence-based treatment knowledge. The challenge is that specialist medical toxicologists are concentrated in tertiary centers and may not be physically available at the site of exposure.

Telemedicine enables the delivery of specialist expertise without requiring physical co-location. In toxicology, remote consultation is not entirely new: poison centers have long provided telephone-based advice to clinicians and the public. Modern digital systems now extend this model through video, secure messaging, electronic medical records, image transmission, remote monitoring, and decision-support systems. An early review in the Journal of Medical Toxicology described toxicologists as pioneers of telemedicine. It showed how remote video could help identify a characteristic toxidrome in a child with suspected envenomation [1].

The World Health Organization (WHO) defines telemedicine as the delivery of health services when distance is a critical factor, using information and communication technologies to exchange information for diagnosis, treatment, prevention, research, evaluation, and professional education [2]. WHO's current Global Strategy on Digital Health has been extended through 2027 and emphasizes equitable access, people-centered care, interoperability, privacy, cybersecurity, sustainability, and evidence-based digital transformation [3-4].

Clinical toxicology is particularly well suited to telemedicine because many consultations are knowledge-intensive rather than procedure-intensive. A toxicologist can provide substantial clinical value by interpreting exposure data, estimating risk, reviewing ECGs and laboratory results, recommending monitoring, and helping to determine disposition. This review aims to synthesize the clinical applications, evidence, limitations, and future directions of telemedicine in clinical toxicology.

Methods of Literature Search

A narrative literature search was conducted using PubMed and web-based searches of peer-reviewed medical literature and authoritative digital health documents. Search concepts included combinations of "telemedicine," "telehealth," "tele-toxicology," "medical toxicology," "poison control center," "poison information service," "toxicology consultation," "poisoning," "envenomation," "chemical disaster," "digital health," "HL7 FHIR," and "artificial intelligence." Priority was given to peer-reviewed clinical toxicology studies, systematic reviews, implementation studies, and official WHO documents or standards. Recent literature up to 2026 was considered when available. As this was a narrative review rather than a systematic review or meta-analysis, no formal risk-of-bias assessment or quantitative pooling was performed.

Concept and Scope of Tele-Toxicology

Tele-toxicology can be understood as a continuum of remote clinical services. At its simplest, it is a telephone consultation between a treating clinician and a toxicologist. More advanced models include video assessment, asynchronous electronic consultation, transmission of ECGs and laboratory data, photographs of products or plants, remote monitoring, and integration with electronic health records.

The principal components of a tele-toxicology encounter are similar to those of bedside toxicology: exposure identification, dose estimation, route and timing assessment, patient-specific risk factors, toxidrome recognition, severity assessment, treatment planning, disposition, safety-netting, and follow-up. The difference is that these tasks are supported by digital communication and shared information rather than physical co-location.

To improve conceptual clarity, the review is organized into four interconnected domains: (1) individual patient care, including emergency-department and inpatient consultation, pediatric poisoning, drug poisoning, envenomation, and community management; (2) poison-center and specialist toxicology consultation models; (3) public-health and population-level applications, including toxicovigilance, surveillance, and chemical incidents; and (4) health-system and digital infrastructure, including interoperability, governance, cybersecurity, and emerging decision-support technologies. The level and nature of evidence differ across these domains: clinical and poison-center applications are supported mainly by observational studies, service evaluations, and implementation studies, whereas national infrastructure, interoperability, remote monitoring, and artificial intelligence remain more dependent on

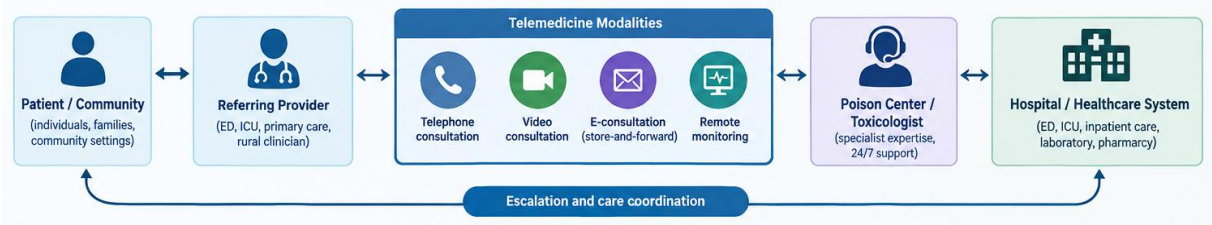


Figure 1. Applications of telemedicine in clinical toxicology. The framework illustrates how remote toxicology services can support individual patient care from exposure assessment and toxidrome recognition through treatment planning, monitoring, disposition, safety-netting, and follow-up. Communication modalities include telephone consultation, video assessment, asynchronous electronic consultation, transmission of clinical data and images, and selected remote-monitoring approaches. The bedside clinician remains responsible for immediate stabilization and physical examination, while the remote toxicologist provides specialist interpretation and management guidance.

implementation experience, technical frameworks, and extrapolation from adjacent fields. Established findings are distinguished from emerging or investigational applications throughout the review.

Tele-toxicology should therefore not be equated with "video visits." A robust service can use multiple modalities based on urgency and available bandwidth. Telephone remains highly effective for immediate consultation, whereas video can provide additional visual clinical information. Asynchronous consultation may be useful for non-urgent cases, education, and review of laboratory or imaging information. The optimal system is multimodal and escalation-oriented (Figure 1).

Clinical Applications in Individual Patient Care

Emergency department and inpatient consultation

The most direct application is real-time consultation in emergency departments, intensive care units, and inpatient wards. The toxicologist may assist with identifying an agent, interpreting a toxidrome, assessing the ECG, selecting laboratory tests, administering antidotal therapy, implementing enhanced elimination, determining monitoring requirements, and determining disposition. This model is particularly valuable when a hospital has emergency physicians and critical-care resources but no on-site toxicologist.

Poison control and poison information services

Poison centers are an established form of remote toxicology. Telephone and digital information services can provide exposure-specific risk assessments for the public and healthcare professionals. Evidence suggests that these services can reduce unnecessary emergency department referrals. In the UK, NPIS telephone advice reduced the proportion of primary care cases considered appropriate for ED referral from 58.1% before consultation to 40.4% after consultation; TOXBASE guidance produced a smaller but significant reduction [5].

Community management and home observation

A major value of tele-toxicology is its ability to identify low-risk exposures that can be safely observed outside the hospital, while providing explicit safety-netting. A remote consultation should specify expected symptoms and warning signs, outline follow-up, and provide clear instructions for emergency escalation.

Pediatric poisoning

Children frequently experience accidental exposures to medications and household products. Remote toxicology services can help identify products from packaging photographs, calculate weight-based risk, and determine whether an emergency evaluation is needed. Historical poison-center research demonstrated substantial reductions in unnecessary pediatric hospital visits among families who contacted a poison center [6].

Pharmaceutical and recreational drug poisoning

Overdose involving cardiovascular drugs, antidepressants, acetaminophen, salicylates, opioids, sedatives, and other agents often requires interpretation of dose, timing, ECG, laboratory data, and co-ingestion. A centralized toxicologist can provide standardized recommendations across hospitals.

Envenomation

Video can be particularly useful when visual findings are important. A 2025 report from a regional poison center described statewide telemedicine consultation for snakebite cases. Among 140 eligible encounters in which consultation was offered, video consultation was performed in 84 (60%). Interfacility transfer was less frequent when telemedicine

consultation was performed than when it was not [7].

Rural and resource-limited settings

A telephonic medical toxicology service in Lebanon demonstrated the feasibility of providing specialist toxicology expertise in a low-resource setting [8]. These models may reduce geographic disparities and support clinicians who manage poisoning infrequently.

Public Health and Population-Level Applications

Chemical incidents and mass-casualty events

Remote toxicology consultation can support incident recognition, triage, decontamination guidance, antidote selection, hospital coordination, and surveillance during chemical incidents. In disasters, the value of a centralized expert pool may increase because multiple facilities can simultaneously access the same network of specialists (Figure 2).

Evidence of Clinical Impact

The strongest evidence for the value of remote toxicology comes from poison-center systems, which have accumulated decades of clinical and economic experience. A systematic review of economic evaluations found poison centers to be economically viable; reported cost-benefit ratios ranged from 0.76 to 7.67, with several studies suggesting substantial healthcare savings [9]. A multi-year analysis of the Utah Poison Control Center estimated that approximately 20,000–24,200 emergency department visits could be prevented annually, corresponding to $16.6–$24.4 million in averted hospital charges [10]. These figures are estimates based on reported hypothetical behavior and hospital charges rather than randomized evidence, and they should not be generalized directly to every health system.

Remote toxicology consultation may also affect hospital utilization after admission. Observational studies have reported shorter hospital stays among poisoned patients who received poison-center assistance [11-12]. A 2022 U.S. study of hospitalized poisoned patients found that poison-center consultation was associated with an 11.6-hour shorter mean hospital length of stay; the analysis was retrospective and therefore does not establish causation [13].

National-scale digital toxicology programs provide additional evidence of feasibility. A 2025 nationwide study in Saudi Arabia described digital toxicology teleconsultations for adult poisoning cases across

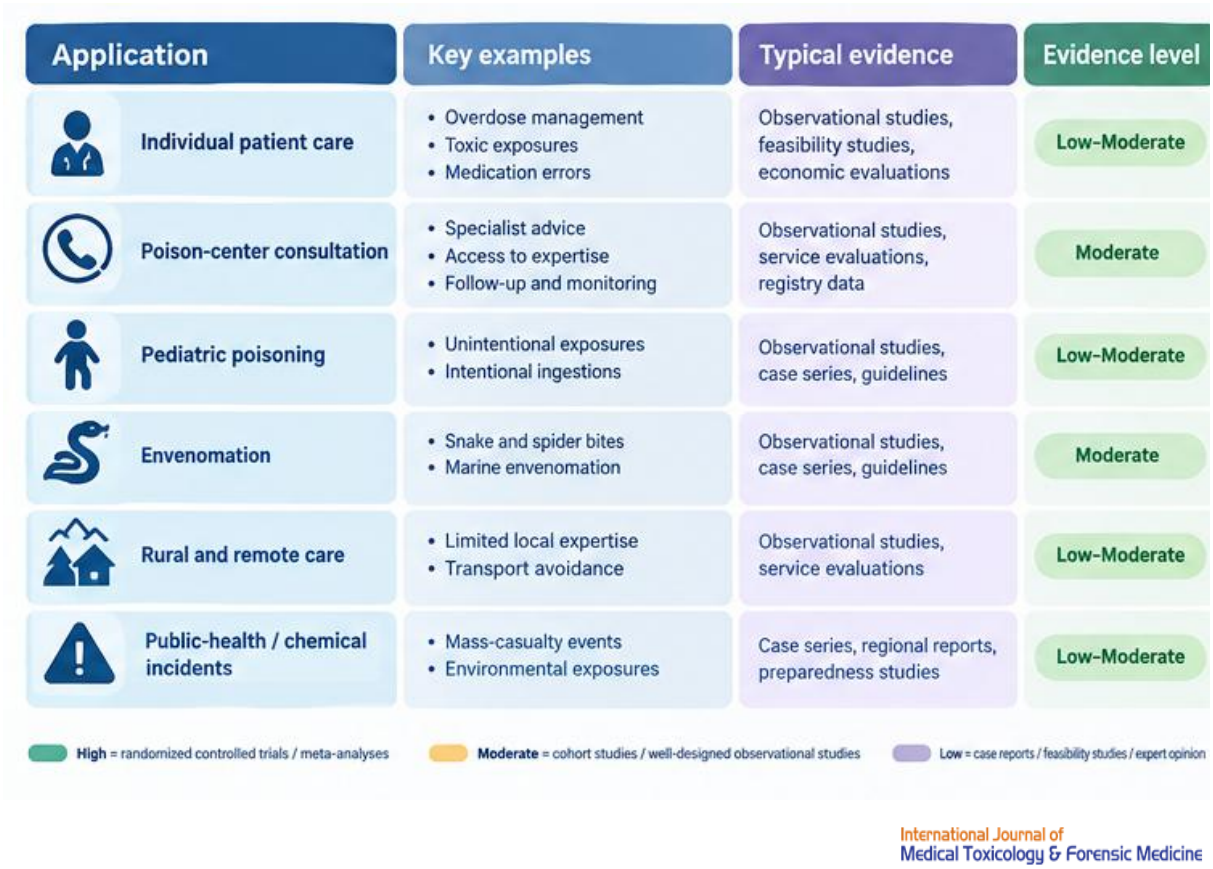


Figure 2. Clinical applications of telemedicine in clinical toxicology and evidence domsains.

hospitals [14]. A separate 2025 nationwide analysis of public toxicology calls reported 39,142 consultations in 2023, illustrating the potential scale of centralized tele-toxicology [15]. A 2026 analysis further characterized teleconsultations for pharmaceutical poisoning and showed that consultation data can be used to describe exposure patterns and disposition decisions [16].

Taken together, the available evidence supports potential effects at three levels: individual patient care, healthcare-system utilization, and population-level surveillance. However, prospective controlled studies that isolate the effect of a specific telemedicine modality on patient-centered clinical outcomes remain limited. Accordingly, the evidence should be interpreted primarily as evidence for specialist toxicology consultation and service delivery, rather than as definitive proof of the superiority of one remote technology over another.

Poison-Center and Specialist Toxicology Consultation Models

A hub-and-spoke model is especially attractive for countries with uneven distributions of specialists. A central toxicology hub can provide 24/7 consultation for regional hospitals, while local clinicians remain responsible for immediate stabilization and bedside care. The same hub can also handle poison-center calls from the public and maintain a shared knowledge base.

A national service should include standardized intake fields, escalation criteria, documentation templates, and quality indicators. Centralized staffing can improve consistency, while regional expertise can address local toxicants and languages. The model can scale from telephone-only systems to integrated video and electronic consultations.

The low-resource telephonic service reported from Lebanon shows that sophisticated infrastructure is not an absolute prerequisite. A practical implementation can begin with reliable telephone access, standardized protocols, trained consultants, and secure documentation, then add video and interoperability as resources mature (Figure 3) [8].

Health System and Digital Infrastructure

Tele-toxicology becomes substantially more powerful when consultation data can be securely shared among the poison center, emergency department, laboratory, ambulance service, and public health system. Interoperability reduces duplicate data entry and improves continuity of care.

Health Level Seven International Fast Healthcare Interoperability Resources (HL7 FHIR) is a standard for representing and exchanging health information. WHO has highlighted FHIR as an important component of standards-based interoperability in digital health [17-20].

A toxicology-specific implementation guide could also standardize data elements such as agent, formulation, route, dose, time of exposure, toxidrome, antidote, disposition, and outcome. Structured data would improve clinical communication and support surveillance and research.

Interoperability should be both syntactic and semantic. Terminology and controlled vocabularies are required to ensure consistent representation of “acetaminophen,” “paracetamol,” and related concepts. WHO's current digital health work emphasizes both data standards and computable clinical guidance [19-21].

Emerging Technologies and Future Directions

Artificial intelligence (AI) is likely to become an important adjunct to tele-toxicology, but its implementation should proceed cautiously. Potential applications include automated extraction of exposure histories, product identification from images, literature retrieval, dose and time calculations, risk stratification, detection of abnormal electrocardiogram (ECG) patterns, and population-level surveillance.

Recent reviews highlight a rapidly expanding role for AI and machine learning in toxicology, including predictive toxicology, big data analysis, and clinical decision support. Generative AI may also enable rapid retrieval and summarization of toxicology literature. However, the risks of hallucinations, hidden bias, nontransparent reasoning, and outdated recommendations are particularly important in acute poisoning.

The appropriate model is therefore “AI-assisted toxicology,” not autonomous toxicology. AI outputs should be transparent, traceable to validated sources, and subject to review by toxicologists or clinicians. High-risk recommendations—such as administering an antidote, performing invasive treatment, or discharging a patient—should require human oversight. AI governance should address validation, monitoring, auditability, data provenance, cybersecurity, and accountability [22-29].

Advantages

Telemedicine offers several potential advantages in clinical toxicology. First, it improves access to expertise without requiring travel. Second, it can

shorten the time between exposure and specialist decision-making. Third, centralized expertise can standardize care and reduce variation across facilities. Fourth, remote triage can identify low-risk exposures suitable for home observation and reduce unnecessary emergency transfers. Fifth, digital documentation generates a valuable dataset for surveillance, quality improvement, and research. Sixth, telemedicine supports education and mentorship for clinicians who encounter poisoning less frequently [30-32]. For example, Hamyar Masmoomin, meaning "Poisoning Assistant," is an application developed in Iran and available on the Masmumin. Their website has been a great help. The development of this WordPress-based web application for poisoning patient assessment represents a significant step towards modernizing medical education [33].

Economic evidence from poison centers is particularly relevant. The systematic review by Galvao and colleagues found favorable economic evaluations across multiple settings [9], and more recent analyses have quantified the potential to avoid ED visits and hospital charges [10]. These findings support the hypothesis that tele-toxicology can be both clinically useful and economically efficient, although local economic evaluations remain necessary.

Limitations, Safety, and Ethical Issues

Telemedicine does not eliminate the need for bedside assessment. Critically ill patients require immediate management of the airway, breathing, circulation, seizures, and arrhythmias. Remote consultation must never delay resuscitation or transfer.

The major clinical limitation is an incomplete physical examination. Subtle neurological findings, perfusion abnormalities, evolving respiratory failure, and certain dermatologic findings may be difficult to assess remotely. Uncertain exposure histories remain common.

Technical barriers include poor connectivity, inadequate devices, software incompatibility, and system downtime. The digital divide can disproportionately affect rural or disadvantaged populations. Privacy and cybersecurity are additional concerns because toxicology consultations may contain sensitive information [34-35].

Legal and ethical questions include professional licensure, cross-border practice, medico-legal responsibility, informed consent, documentation, data retention, and reimbursement. A clear governance framework should define the responsibilities of the remote toxicologist and the bedside clinician [21,35].

WHO's digital health strategy emphasizes privacy, security, patient safety, ethics, interoperability, affordability, and cost-effectiveness as core principles [3-4]. These principles should be explicitly integrated into tele-toxicology programs.

Quality Assurance and Outcome Measurement

A mature tele-toxicology service should use predefined quality indicators. Process measures can include time to answer, time to toxicologist consultation, documentation completeness, and the proportion of cases successfully managed remotely. Clinical measures can include adverse events, unexpected deterioration, ICU admission, antidote administration, transfer, and return visits.

Patient-centered measures should include satisfaction, understanding of safety-netting instructions, and confidence in the management plan. System-level measures should include avoided transfers, avoided ED visits, length of stay, cost-effectiveness, and staff satisfaction.

Importantly, “low hospital referral” should not be used as a success metric on its own. A service that fails to make appropriate transfers may harm patients. Therefore, quality assessment requires balancing

Table 1. Practical tele-toxicology quality indicators.

Domain	Examples	Interpretation
Access	Response time; availability; failed connections	Measures timeliness and reliability
Clinical safety	Unexpected deterioration; inappropriate discharge; delayed transfer	Core patient-safety domain
Utilization	Avoided ED visits; transfers; length of stay	System efficiency
Clinical process	Documentation completeness; guideline adherence	Standardization
Patient experience	Satisfaction; understanding of safety-netting	Person-centered care
Economic	Cost per consultation; cost per avoided transfer	Value and sustainability

utilization outcomes with safety outcomes (Table 1).

Proposed National Tele-Toxicology Model

A national model can be organized around a centralized toxicology hub that links to public poison centers, emergency medical services, hospitals, laboratories, and public health authorities. The hub would provide continuous consultation, structured documentation, protocol support, education, and surveillance.

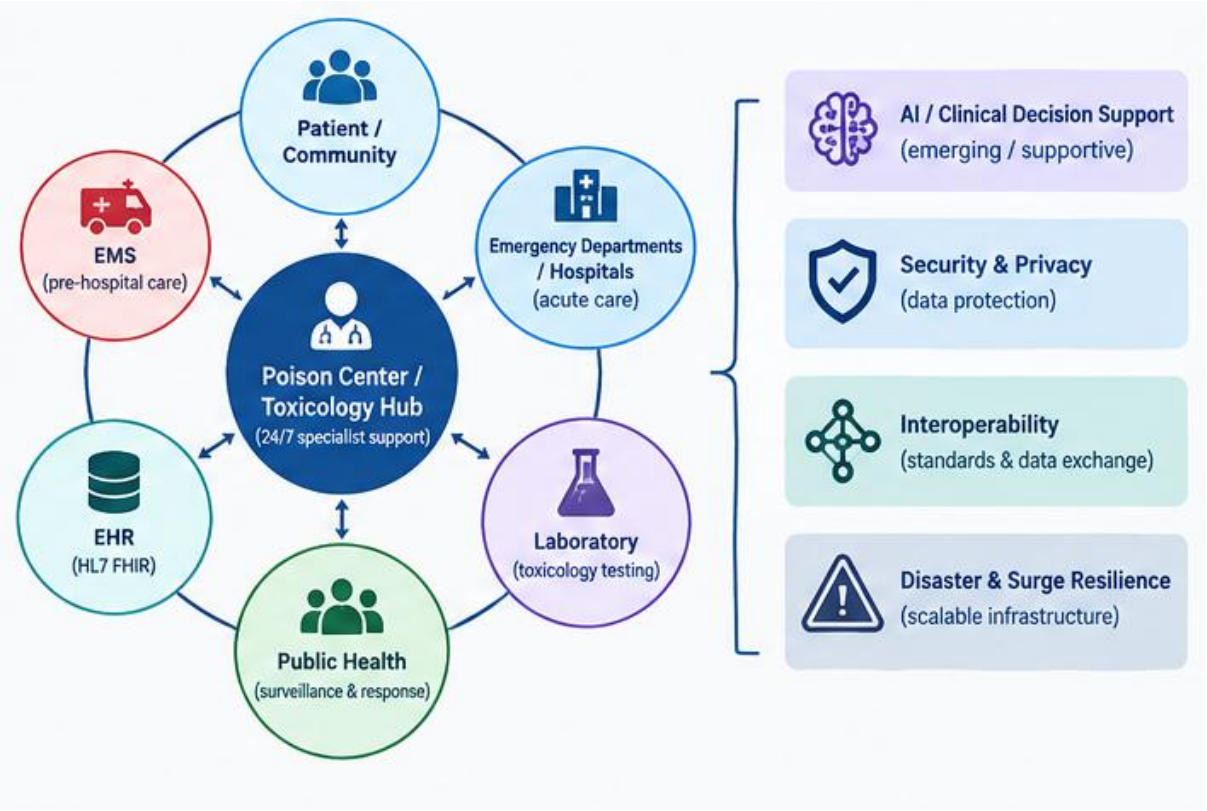
The architecture should include five layers: (1) access points; (2) a secure tele-toxicology platform; (3) toxicology expertise; (4) interoperable clinical information systems; and (5) outcome and surveillance analytics. HL7 FHIR can provide a technical foundation for standardized data exchange, and local clinical protocols define the decision logic.

The system should be designed to degrade gracefully. If the video fails, the telephone should remain available. If the electronic health record (EHR) interface is unavailable, a secure fallback process should be in place. Disaster planning should include redundancy, cybersecurity, surge staffing capacity, and cross-regional backup (Figure 3).

Future Directions

The future of tele-toxicology is likely to involve integration rather than replacement. Telephone consultations will remain important for their speed and accessibility. Video and voice-over-internet-protocol (VoIP) communication can enable additional assessment. Mobile health applications may support structured data capture and remote follow-up. Selected remote-monitoring approaches may eventually assist with post-discharge observation, but their safety and effectiveness in acute poisoning require prospective evaluation. Interoperable EHR systems may reduce information fragmentation. AI and clinical decision support systems may assist clinicians with information retrieval, risk stratification, and surveillance, but should remain subject to clinical oversight.

At the population level, national tele-toxicology networks could provide near-real-time surveillance of poisoning trends. Aggregated data could identify unusual clusters of exposure, emerging recreational drugs, counterfeit products, occupational incidents, and



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Figure 3. Proposed architecture for a national tele-toxicology service. The model connects patients, emergency services, hospitals, laboratories, poison centers, toxicology specialists, and public-health authorities through secure communication and information exchange. Core components include access points, specialist expertise, standardized documentation, interoperable clinical information systems, surveillance functions, and quality and outcome measurement. The architecture can support telephone consultation and can be expanded to video consultation and electronic data exchange as infrastructure permits.

Table 2. Summary of clinical and health-system evidence for tele-toxicology and remote toxicology consultation. The table distinguishes evidence for specialist toxicology/poison-center services from evidence specific to a telemedicine modality.

Study	Design	Population/setting	Telemedicine modality/ service	Comparator	Outcomes	Principal findings	Key limitations
Galvão et al., 2011 [12]	Retrospective cohort	198 hospitalized poisoned patients, Brazil	Remote poison-center assistance	No poison-center assistance	Hospital length of stay	Consultation was associated with 3.43 fewer hospital days	Observational; single setting; residual confounding
Elamin et al., 2018 [5]	Service evaluation/ observational	UK primary-care poisoning contacts	National Poisons Information Service advice	Historical/alternative referral patterns	ED referral	The proportion considered appropriate for ED referral fell after specialist advice	Non-randomized; service-level analysis
Tak et al., 2017 [10]	Multi-year observational/ economic analysis	Utah Poison Control Center	Poison-center consultation	Modeled/hypothetical non-caller behavior	Potential ED visits and hospital charges	Estimated 20,000–24,200 potentially avoidable ED visits/year and $16.6–$24.4M in charges	Estimates partly based on hypothetical behavior and charges
Hitti et al., 2021 [8]	Implementation/ feasibility report	Low-resource setting, Lebanon	Telephone medical toxicology service	No formal comparator	Feasibility and service delivery	Demonstrated feasibility of specialist toxicology consultation in a low-resource setting	No controlled clinical outcomes
Farkas et al., 2022 [13]	Retrospective observational study	127,224 hospitalized poisoning cases in the U.S.	Poison-center consultation	No consultation	Length of stay and hospital charges	Consultation was associated with shorter length of stay	Observational; not modality-specific; potential confounding
Alharbi et al., 2025 [14]	Nationwide retrospective/service analysis	6,427 adult poisoning cases, Saudi Arabia	Digital toxicology teleconsultation	No comparator	Clinical characteristicsdisposition, service utilization	Demonstrated national-scale feasibility and standardized consultation	No comparator; limited causal inference
Snakebite telemedicine study, 2025 [7]	Observational service evaluation	140 eligible snakebite consultations	Video versus non-video teleconsultation	Video vs non-video	Interfacility transfer	Transfer was less frequent with video consultation	Non-randomized; possible selection bias; not proof of causation

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environmental contamination.

Research priorities include prospective studies comparing telemedicine-supported care with usual care; validation of remote triage tools; cost-effectiveness studies in low- and middle-income countries; standardized safety indicators; evaluation of artificial-intelligence systems; and development of international interoperability standards for toxicology data. These priorities are informed by the current clinical evidence and by general telemedicine technology literature, but emerging technologies should not be interpreted as established acute-toxicology interventions (Table 2) [36].

Conclusion

Telemedicine can extend specialist toxicology expertise across geographic and institutional boundaries and may reduce unnecessary healthcare utilization in selected settings. The most established evidence concerns poison-center and specialist consultation services, whereas evidence for the independent effect of specific telemedicine modalities and for patient-centered outcomes remains limited. Future research should prioritize prospective

comparative studies, standardized safety and patient-centered endpoints, interoperability, cybersecurity, governance, and validation of emerging artificial intelligence and remote monitoring tools.

Available evidence indicates that poison-center and tele-toxicology services can reduce potentially unnecessary emergency utilization and may shorten hospital stays, while national digital programs demonstrate scalability. Nevertheless, the evidence base for patient-centered outcomes remains less mature than that for feasibility and utilization.

Emerging applications such as remote monitoring, wearable sensors, mobile applications, and artificial intelligence may eventually extend follow-up and decision support in selected poisoning cases. However, evidence from chronic-disease monitoring and general digital health cannot be assumed to demonstrate safety or effectiveness in acute poisoning. These technologies should therefore be considered investigational in this context until supported by toxicology-specific prospective studies.

The most appropriate future model is an integrated ecosystem in which the bedside clinician remains responsible for immediate stabilization, the toxicologist provides specialist interpretation, digital systems enable secure information exchange, and AI supports—not replaces—clinical judgment. With appropriate governance, interoperability, cybersecurity, and prospective evaluation, tele-toxicology could become a core component of equitable, efficient, and resilient poisoning care.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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