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## Methanol Poisoning as a Critical Emergency: Clinical, Diagnostic, and Systemic Challenges in Emergency Care

*Methanol Poisoning as a Critical Emergency: Clinical, Diagnostic, and Systemic Challenges in Emergency Care*

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### Summary

Methanol poisoning is a highly lethal medical emergency associated with severe metabolic acidosis, central neurological impairment, and a high risk of irreversible blindness.

Although relatively uncommon in everyday practice, episodes of collective exposure related to adulterated alcoholic beverages and illicit products continue to be reported in different regions of the world, with a significant impact on emergency services and health systems. This article presents a critical review of the pathophysiology, clinical presentation, and diagnostic and therapeutic strategies of methanol poisoning, with an emphasis on decision-making in emergency settings. It also discusses the organization of care in outbreak scenarios, the limitations of timely laboratory diagnosis, and the ethical and regulatory challenges involved. The analysis integrates consolidated clinical evidence and international guidelines, reinforcing the importance of early suspicion, timely use of antidotes, and hemodialysis as prognostic determinants.

**Keywords:** methanol poisoning; medical emergency; metabolic acidosis; optic neuropathy; fomepizole; hemodialysis.

### Abstract

Methanol poisoning is a life-threatening medical emergency characterized by severe metabolic acidosis, central nervous system injury, and a high risk of irreversible visual impairment. Although relatively infrequent in routine emergency practice, recurrent outbreaks associated with adulterated alcoholic beverages and illicit products continue to be reported worldwide, placing substantial strain on emergency care systems. This article provides a critical review of methanol poisoning pathophysiology, clinical manifestations, diagnostic strategies, and management in emergency settings. Attention is given to decision-making under diagnostic uncertainty, outbreak response, and system-level challenges. By integrating established clinical evidence and international guidelines, this review highlights early clinical suspicion, timely antidotal therapy, and hemodialysis as key determinants of patient outcomes.

**Keywords:** methanol poisoning; emergency medicine; metabolic acidosis; optic neuropathy; fomepizole; hemodialysis.

### Introduction

Methanol poisoning remains one of the most serious forms of poisoning.

exogenous, not because of how frequently it occurs, but because of the severity of its clinical consequences. Unlike ethanol, which is widely used and regulated for human consumption, methanol is a alcohol for industrial use, employed as a solvent, fuel, and chemical input, without any therapeutic or recreational indication. However, its presence in adulterated alcoholic beverages or The use of illegal products has been repeatedly documented, turning avoidable exposures into... events with a high health impact.

From a practical emergency standpoint, methanol poisoning presents challenges specific. The onset of the condition is usually insidious, with nonspecific symptoms that mimic the

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Alcohol intoxication is common, contributing to diagnostic delays. When the symptoms are more pronounced...

Severe symptoms become evident — intense metabolic acidosis, neurological changes and

Visual impairment — tissue damage is often already present. In these scenarios, the

The therapeutic window is narrow, and clinical decisions need to be made even in the absence of...

definitive laboratory confirmation.

Beyond the individual aspect, episodes of methanol poisoning often involve...

of a collective nature, forming outbreaks that overwhelm emergency services and intensive care units.

Intensive care and dialysis centers. Such events expose weaknesses in health surveillance and regulation.

of the alcoholic beverage market and the responsiveness of health systems, especially

in contexts of social inequality and economic informality.

This article critically reviews the main aspects of methanol poisoning under the  
From an emergency care perspective, articulating pathophysiology, clinical aspects, diagnosis, and management.  
therapeutic, and discussing systemic and public health implications associated with outbreaks.

### **Pathophysiology of methanol poisoning**

Methanol itself has relatively low toxicity; serious effects result from...  
primarily from its metabolites. After ingestion, methanol is rapidly absorbed by the digestive tract.  
Gastrointestinal and distributed throughout total body water. In the liver, alcohol dehydrogenase converts the  
Methanol is converted into formaldehyde, which is subsequently oxidized by aldehyde dehydrogenase to acid.  
Formic acid. The latter is primarily responsible for metabolic acidosis and neurological toxicity.  
and ocular.

The accumulation of formic acid leads to the inhibition of cytochrome c oxidase in the respiratory chain.  
mitochondrial, with impaired oxidative phosphorylation and energy production. Tissues with high  
metabolic demand and rich mitochondrial activity, such as in the retina, optic nerve, and nuclei of  
The white matter in the brain becomes particularly vulnerable, which explains the tropism of  
Methanol poisoning affects the optic pathway and deep structures of the central nervous system.

From a metabolic point of view, the conversion of methanol to formic acid results in acidosis.  
Metabolic syndrome with a high anion gap. Severe acidosis, associated with hyperlactatemia, contributes to  
Hemodynamic instability, central nervous system depression, and diffuse cellular injury. A  
The intensity of acidosis is related both to the amount of methanol ingested and the interval...  
between ingestion and the start of treatment.

The severity of the poisoning varies depending on the cosmetic dose and the concentration of the substance.  
It is estimated that ingesting approximately 10 milliliters of concentrated methanol can cause harm.  
Permanent neurological damage, including blindness, while doses around 30 milliliters are  
potentially lethal, although there is great interindividual variability.

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## Epidemiology and outbreak contexts

Although methanol poisoning is relatively infrequent in daily practice...

Emergency services, large-scale outbreaks have been repeatedly documented in various continents, often with substantial underreporting. Recent reviews suggest thousands of cases and deaths in outbreaks linked to adulterated beverages in countries in Asia, the Middle East, and Europe. Eastern Europe and the Americas, creating a "recurring and barely visible crisis," frequently concentrated in vulnerable populations.

In the Americas region, PAHO analyses indicate that epidemics of poisoning by Methanol poisoning tends to occur in contexts of informal alcohol consumption, artisanal production, or... clandestine production of distilled spirits and, in some scenarios, in response to prohibitions or severe restrictions on sales. of alcoholic beverages. During the COVID-19 pandemic, for example, an increase was documented. A significant number of cases have been reported in countries that have recorded consumption of disinfectant products or alcohol. industrial issues stemming from misinformation or a shortage of ethyl alcohol for consumption.

These outbreaks often share characteristics: beginning with few severe cases in emergency and intensive care services; retrospective identification of a common source (batch of beverage, clandestine producer, "artisanal" product); and, often, delays in the recognition of The problem is framed as a public health event, which delays surveillance actions and the withdrawal of products from the market. Market and risk communication to the population.

## Clinical picture in an emergency setting.

From a clinical point of view, methanol poisoning presents three main dimensions: Nonspecific initial symptoms, progression to metabolic acidosis and, in many cases, the onset of Optic neuropathy and central neurological damage.

In the first few hours after ingestion, the symptoms may resemble those of ethanol poisoning: Nausea, vomiting, malaise, abdominal pain, headache, dizziness, and a feeling of prolonged drunkenness. This phase is misleading because the patient may not seek care or may be underestimated during triage.

After a latency period that usually varies between 6 and 24 hours – but can be longer. If there is co-ingestion of ethanol, which competes for alcohol dehydrogenase, then the following begin to predominate Signs of metabolic acidosis: compensatory hyperventilation, tachypnea, tachycardia, hypotension, Decreased level of consciousness and, in severe cases, seizures and coma. Laboratory tests. These typically reveal metabolic acidosis with an elevated anion gap, and there may be an increase in the gap. osmolar when specific dosages are available.

Eye symptoms are a central element of the clinical picture. Visual disturbances may occur. early onset, with blurred vision, scotomas, photophobia, and a sensation of visual "fog," progressing to Some cases involve sudden, bilateral vision loss. Examination of the fundus of the eye may reveal edema.

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optic disc and retinal vascular changes. Even with proper treatment, some of the

Patients develop permanent toxic optic neuropathy, resulting in irreversible blindness.

In an emergency setting, suspicion of methanol poisoning should arise when:  
combination of a history of consuming beverages of dubious origin or industrial products,  
Gastrointestinal and neurological symptoms, unexplained metabolic acidosis, and visual disturbances.  
A definitive diagnosis may require serum methanol levels, which are not available in many services.  
which reinforces the importance of syndromic diagnosis based on clinical and laboratory data.  
basics.

### **Laboratory diagnosis**

Although specific serum methanol levels are the gold standard for confirmation  
In practice, exposure is often inaccessible or takes longer than the available time slot.  
for therapeutic intervention. Therefore, diagnosis in an emergency setting is based on the association  
between history, physical examination, and compatible laboratory findings.

The most useful tests include arterial blood gas analysis, electrolytes, renal function tests, blood glucose, and...  
When possible, calculate the anion gap and the osmolar gap. The presence of metabolic acidosis of  
High intensity, with a high anion gap, associated with an increased osmolar gap, is highly  
suggestive of poisoning by toxic alcohols (methanol or ethylene glycol), especially in the presence of  
Compatible story.

Other findings may include hypokalemia, hypocalcemia, and mild elevation of transaminases.  
Leukocytosis and signs of acute kidney injury. Imaging studies, such as computed tomography or  
Magnetic resonance imaging (MRI) of the brain can reveal lesions in the basal ganglia, particularly in the...  
putamenes, and areas of demyelination in the white matter, especially in later stages.  
advanced, although not necessary for initial diagnosis.

Given that time is a critical factor, it is recommended that the decision to institute treatment be made...  
The specific diagnosis should not be postponed until laboratory confirmation of methanol, whenever the set of  
Clinical and laboratory findings indicate a high probability of poisoning.

### **Management in emergency and urgent care services**

Treatment for methanol poisoning relies on three main pillars: clinical support  
In general, it blocks the metabolism of methanol and removes toxins and their metabolites.  
Clinical support includes airway stabilization, ventilation and circulation, and monitoring.  
intensive care, correction of hydroelectrolytic disturbances and management of neurological complications and  
Hemodynamic changes. Severe metabolic acidosis should be treated with intravenous sodium bicarbonate.  
with the aim of improving hemodynamic status and reducing the penetration of formic acid into the system

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central nervous system and buy time until antidotes and hemodialysis can take effect.

The second component is the inhibition of methanol metabolism. Both ethanol and Fomepizole acts as a preferred substrate for hepatic alcohol dehydrogenase, preventing the... Formation of formaldehyde and formic acid. Classic guidelines from the American Academy of Clinical Toxicology and recent reviews indicate that both may be effective, but point to fomepizole. as the antidote of choice, due to its more favorable safety profile and greater predictability. pharmacokinetics. In scenarios where fomepizole is not available, intravenous or oral ethanol. It remains a viable alternative, although it requires rigorous monitoring and may carry a higher risk of Hypoglycemia, sedation, and drug interactions.

The third pillar is the removal of circulating methanol and formic acid. Hemodialysis. Intermittent drinking is the preferred method because it allows for the rapid elimination of alcohol and its metabolites. correcting both acidosis and electrolyte disturbances simultaneously. The main indications for The complications of hemodialysis include severe metabolic acidosis, deterioration of neurological status, and acute kidney injury. Significant and elevated levels of methanol when these dosages are available.

Additionally, the use of folinic acid (or folic acid, when folinic acid is not available) is recommended. (is available) to accelerate the metabolism of formic acid to carbon dioxide and water, contributing to reducing toxicity.

In many countries, national guidelines and documents from medical societies of Emergency and toxicology experts emphasize that, given a consistent clinical suspicion of poisoning by methanol, initiation of antidote therapy and, when necessary, transfer to a service with Hemodialysis capability should not await definitive laboratory confirmation.

### **Organization of care and preparedness for outbreaks.**

Beyond individual management, methanol poisoning in an emergency setting presents... Specific requirements for universal health systems. In outbreak situations, emergency services Referral centers and hospitals can receive a large number of patients in a short period of time. time, many in critical condition, simultaneously requiring intensive care beds, Hemodialysis and expensive antidotes.

WHO and PAHO guidelines on methanol poisoning outbreaks highlight some Preparation axes: strengthening epidemiological surveillance with timely notifications of suspected cases, standardization of clinical records to include specific fields for suspected cases. Toxic alcohol, definition of referral hospitals for the management of severe cases, guarantee of stocks. minimum quantities of antidotes and hemodialyzers and development of simplified clinical protocols For use in emergency services.

In the Brazilian context, these challenges are linked to the structure of the Healthcare Network.

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Emergency services within the Brazilian Unified Health System (SUS). Urgent care units, general hospitals, and centers.

Specialists need to establish clear workflows for identifying and referring cases.

ensuring that patients suspected of methanol poisoning can be quickly assessed,

receive adequate initial support and, when indicated, be transferred to centers with the capacity.

hemodialysis and access to the antidote. In regions where such resources are scarce, coordination

Regional considerations and the prior definition of benchmarks become even more important.

Coordination with health surveillance agencies is equally crucial. Once identified

In the first cases, it becomes urgent to trace the source of the poisoning, collect suspected batches, and ban production.

establishments and communicate the risks to the public transparently, avoiding so much panic.

Unnecessary regarding the continuation of the exhibition.

### **Ethical and public policy challenges**

Methanol poisoning, especially when related to adulterated beverages,

It involves issues that go beyond the strictly clinical field. It is a phenomenon that crosses...

Social inequalities, economic informality, crime, and regulatory failures. In many

In these contexts, the victims are low-income individuals who resort to cheaper or locally produced beverages.

informally, or populations that consume alcohol under conditions of prohibition and stigma, which

It makes it difficult to seek early care.

From an ethical standpoint, dilemmas arise regarding access to expensive antidotes and...

Hemodialysis in resource-limited systems. The delivery of fomepizole, for example, requires

Inventory planning and prioritization, so that its availability is not restricted to

Few specialized centers, leaving peripheral services underserved.

There are also tensions between strategies for controlling and suppressing the illicit alcohol market and the  
the need to ensure that intoxicated individuals feel safe to seek treatment, without

fear of sanctions. Criminalizing consumption in some contexts can exacerbate underreporting and

Delaying arrival at the health service worsens the prognosis.

Finally, recurring episodes of methanol in commercial or "craft" beverages expose

Weaknesses in the regulation of supply chains and in market oversight are raising debate.

Regarding the responsibility of companies, traders, and regulatory authorities in preventing these...

tragedies. In universal healthcare systems, where the harm caused by preventable events falls on

with public resources, there is an additional argument for investing in robust regulation and oversight such as

a way to protect both the population and the financial sustainability of the system.

## Final considerations

Methanol poisoning constitutes a highly serious toxicological emergency, whose The clinical course often involves a nonspecific onset followed by rapid progression to acidosis. severe metabolic syndrome, central neurological impairment, and optic neuropathy are frequent irreversible. Although the pathophysiological mechanisms are well described in the literature and there are Despite effective therapeutic strategies, outcomes remain unfavorable in a significant proportion of cases. of the cases, especially when clinical recognition is delayed or when there are limitations in access. specialized treatment.

In an emergency context, improving the prognosis depends fundamentally on high... clinical suspicion, proper interpretation of basic laboratory tests, and readiness to initiate Specific therapies are available even in the absence of definitive laboratory confirmation. availability of antidotes such as fomepizole, timely access to hemodialysis, and adjunctive use folinic acid treatments comprise a set of interventions that, when applied early, They demonstrate the potential to reduce mortality and permanent disabilities.

From the perspective of health systems, the recurring occurrence of international outbreaks The association with adulterated alcoholic beverages indicates that methanol poisoning should not be considered. viewed not as a fortuitous event, but as a manifestation of structural weaknesses related to Product regulation, economic informality, and social inequalities. This scenario demands coordinated responses that integrate epidemiological surveillance, sanitary inspection, and policies of control of the illicit alcohol market, health education strategies and strengthening of problem-solving capacity of emergency services. In universal health systems, the coordination between Emergency care, clinical toxicology, and health surveillance are central elements for detection. Early detection of anomalous patterns and mitigation of collective impacts.

Finally, the experience accumulated in different countries demonstrates that poisoning by Methanol, despite its high lethality, is largely preventable. Investments in regulation, efficient management of the alcoholic beverage production chain, strengthening of clinical and forensic laboratories, Ongoing training of emergency teams and dissemination of simplified clinical protocols. These measures are capable of significantly reducing both the incidence and the lethality. of these events. By incorporating this preventative agenda, universal health systems not only They prepare to respond to serious emergencies, but also reaffirm their commitment to... protection of vulnerable populations and the rational use of public resources.

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