

Toxicological Profiling of Carbolitic Acid and Use of Application Based Questions: An Observational Study

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Abstract: Phenol is a highly lethal, fat soluble, and corrosive agent capable of causing local and systemic toxicity, including central nervous system depression, cardiovascular collapse, and acute renal failure. Given the complex pathophysiology and high mortality associated with phenol poisoning, medical learners face significant challenges in mastering and applying this knowledge clinically. Traditional "teaching as talking" lectures often fall short of preparing students for real world clinical execution, highlighting the need for active and authentic learning strategies. This study evaluates whether integrating authentic, application-based questions into the toxicology curriculum significantly enhances learners comprehension, retention, and practical clinical readiness in managing acute phenol poisoning. An observational study was conducted utilizing a cohort of 45 participants, divided into two groups. Group A consisted of 31 students who were exposed to application-based questions in addition to didactic lectures. Group B consisted of 14 students who received only didactic teaching. The application based core intervention immersed learners in high stakes clinical scenarios, requiring them to synthesize data and formulate immediate action plans rather than relying on rote memorization. The comparative analysis yielded significant differences in learner outcomes between the two teaching methodologies. Participants exposed to application-based questions successfully translated theoretical toxicology into time-critical interventions, showing marked improvement in identifying unique diagnostic clues like "carboluria" (dark green or black urine) and recognizing critical contraindications such as avoiding emesis.

Keywords: Toxicology; Carbolitic Acid; Phenol; Teaching Methods; Poison.

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I. INTRODUCTION

Acute poisoning from phenol, commonly known as carbolitic acid, is a highly lethal medical emergency requiring rapid clinical intervention. Phenol is a fat-soluble, corrosive agent that is readily absorbed through all routes, including ingestion, inhalation, and dermal or mucosal contact.[1] Upon exposure, the toxin exerts profound local and systemic effects. Locally, it damages nerve endings, causing initial tingling that rapidly progresses to numbness, coagulation necrosis, and the formation of a painless, grayish white or opaque eschar. Because the burns are often painless, patients and clinicians may underestimate the severity of the exposure while the poison continues to be systemically absorbed. [2-6]

Once absorbed, phenol systemically attacks the central nervous system (CNS) and cardiovascular system (CVS). It can cause a rapid onset of headache, vertigo, hypothermia, and contracted pupils, ultimately leading to irregular pulse, shock, convulsions, coma, and fatal respiratory or cardiac paralysis.[1] A classic diagnostic hallmark of phenol absorption is "carboluria" a condition where the patient's urine turns a dark, smoky green color due to the renal metabolism of phenol into hydroquinone and pyrocatechol. Surviving these rapid systemic effects requires specific, time-critical decontamination protocols, such as removing the poison from the skin using soap, water, and olive oil or methylated spirit, and performing gastric lavage using activated charcoal, olive oil, or magnesium sulphate.[1]

Given the complex pathophysiology and high mortality associated with phenol poisoning, medical learners face significant challenges in mastering and applying this critical knowledge. In historically challenging, highly conceptual fields like toxicology, relying on traditional "teaching as talking" lectures often falls short of preparing students for real world clinical execution. Effective teaching requires instructors to develop Pedagogical Content Knowledge, the synthesis of subject matter expertise with an understanding of how students actually learn and apply information. To ensure students can translate toxicological theory into life-saving action, educators must diversify their teaching methods by integrating active and authentic learning strategies.

Authentic learning involves designing learning activities and assignments that mirror how students will think and work in the "real world" after graduation. In medical education, application based questions serve as a prime example of authentic learning. Rather than passively memorizing facts, learners are immersed in clinical scenarios where they must identify diagnostic clues (like carboluria or painless eschars) and formulate immediate treatment plans.

To measure the efficacy of this educational approach, this observational study of 45 participants investigates the impact of integrating application based questions into the toxicology curriculum. By simulating the high stakes, time sensitive environment of acute phenol poisoning, this study evaluates whether authentic, application based pedagogy significantly enhances learners comprehension, retention, and practical clinical readiness.

II. MATERIAL AND METHODS

Study Design and Participants: This observational study was conducted to evaluate the efficacy of diversified teaching methodologies in toxicology education. The study cohort comprised 45 participants, who were divided into two groups. Group A included 31 students who were exposed to application-based questions in addition to didactic lectures, while Group B consisted of 14 students who received only didactic lectures. The students in Group B were absent during the scheduled application-based session and therefore had exposure solely to didactic teaching.

The curriculum focused on the pathophysiology, diagnosis, and emergency management of acute phenol poisoning.

Pedagogical Framework: To effectively translate complex toxicological concepts into practical clinical skills, the study's instructional design moved away from traditional "teaching as talking," a method that frequently conflates the instructor's presentation of material with actual student learning. Instead, the curriculum was developed to diversify pedagogy by integrating varying teaching methods, learning activities, and learning assessments. This approach is aimed at building comprehensive Pedagogical Content Knowledge by utilizing evidence based active learning strategies.

Lectures and Video Lectures: Didactic instruction was delivered via both in-person and YouTube video lectures.

Application Based Questions: The core intervention of the study involved application-based questions designed to facilitate "authentic learning" activities that closely mirror how practitioners must think and work in real world clinical emergencies (Table 1). Rather than rote memorization, participants worked through high stakes application questions that required them to synthesize data and formulate immediate action plans, such as recognizing the strict contraindication of emesis or selecting polyethylene glycol over water for skin decontamination.

Assessment and Data Collection: To measure the comparative efficacy of the video lectures, interactive lectures and application-based questions, participants completed a series of assessments which allowed the 45 participants to practice their clinical decision making, learn from their mistakes, and receive timely, formative feedback on their comprehension of phenol toxicity. Furthermore, instructors utilized ongoing feedback from these varied learning activities to critically assess student progress and adapt the pedagogical approach to the learners actual needs.

III. RESULTS

Of the 45 participants enrolled in the observational study, all completed the varied pedagogical interventions and subsequent assessments evaluating their comprehension and clinical readiness regarding acute phenol toxicity. The comparative analysis of the teaching methodologies yielded significant differences in learner outcomes. (Table 2) The most substantial improvements in clinical reasoning were observed following the integration of application-based questions. More than 74% of the students showed a better understanding of phenol poisoning with application based learning compared to their performance following other instructional methods. This authentic learning approach effectively forced students to translate theoretical toxicology into time-critical interventions. For example, participants demonstrated a marked increase in correctly identifying unique diagnostic clues, such as recognizing that a patient's dark green or black urine (carboluria) is a hallmark of systemic phenol absorption. They also consistently recognized critical contraindications, effectively avoiding the induction of emesis due to the high risk of seizures and rapid central nervous system depression

IV. DISCUSSION

Phenol, also known as carbolic acid, is a highly toxic, corrosive, and flammable protoplasmic poison. It is widely utilized in industrial manufacturing, household disinfectants, agricultural products, and medical applications, such as chemical peels, nerve blocks, and the ablation of nailbed matrices.[3,5] Phenol's unique danger lies in its dual hydrophilic and lipophilic properties, which allow it to easily breach cellular membranes, denature and precipitate cellular proteins, and rapidly induce cell death and coagulation necrosis.[3,7] The chemical is readily and rapidly absorbed through all routes of exposure, including inhalation, ingestion, and intact dermal or mucosal contact, leading to wide distribution throughout the body within minutes. Once

absorbed, phenol undergoes first-pass metabolism primarily in the liver, gastrointestinal tract, lungs, and kidneys.[8] It is detoxified mainly via conjugation pathways, predominantly forming phenyl sulfate and phenyl glucuronide, which are then excreted in the urine.[6,9] However, at high toxic doses, the sulfation pathway can become saturated, leading to a decrease in phenol sulfation and a concomitant increase in free phenol and glucuronidation.[9] The systemic administration of phenol via intravenous or injection routes is particularly hazardous because it bypasses the first-pass metabolism of the liver and intestines, exposing organs like the lungs and kidneys to rapidly toxic levels of free phenol.[8,10]

Phenol toxicity affects nearly every major organ system, with the severity of symptoms depending on the dose, concentration, and route of exposure. [1,5,7-15]

Local and Dermal Effects: Contact with phenol initially causes a tingling sensation followed by local anesthesia and numbness, due to its ability to damage nerve endings. It produces a characteristic painless, white, opaque eschar that eventually sloughs off to leave a brown stain.

Central Nervous System (CNS): Phenol directly stimulates and then profoundly depresses the CNS. Patients can rapidly develop headaches, dizziness, muscular spasms, severe convulsions, and deep coma. An unusual neurological complication known as "rabbit syndrome" characterized by rapid, rhythmic perioral movements has also been reported, likely due to phenol inducing cholinergic dominance and relative dopamine hypofunction in the CNS.

Cardiovascular and Respiratory Systems: Phenol exerts severe depressive effects on the vasomotor centers, leading to rapid, irregular pulses, profound hypotension, and cardiovascular collapse. It is notably arrhythmogenic, capable of triggering fatal ventricular arrhythmias, including ventricular fibrillation. Respiratory complications are equally severe, ranging from laryngeal and pulmonary edema to acute respiratory distress syndrome (ARDS) and complete respiratory arrest.

Renal and Hepatic Effects: Acute renal failure is a prominent feature of phenol poisoning. The excretion of unconjugated phenol directly damages the glomeruli and renal tubules, causing tubular necrosis, papillary hemorrhage, and the shedding of protein casts. A classic diagnostic hallmark of phenol absorption is "carboluria," a condition where the patient's urine appears normal or light initially but turns dark green, brown, or black upon exposure to air due to the oxidation of phenol metabolites. Hepatic injury is also common, evidenced by centrilobular necrosis and marked elevations in serum transaminases and bilirubin.

Hematological Effects: In severe cases, phenol acts as a hemolytic agent, causing acute intravascular hemolysis and methemoglobinemia. The subsequent precipitation of hemoglobin in the kidneys can form obstructive casts, further exacerbating acute renal failure.

Chronic Exposure: Long-term exposure to phenol vapors or repeated dermal contact can lead to a condition historically termed "phenol marasmus." This occupational disorder is characterized by progressive weight loss, anorexia, headache, vertigo, and chronically dark urine. Chronic exposure may also cause ochronosis, a bluish-black discoloration of the skin and ocular tissues.

Clinical Management and Decontamination: The rapid absorption of phenol necessitates immediate and aggressive decontamination. [2,4,11,13,15,16]

Gastrointestinal Decontamination: Emesis (inducing vomiting) is strictly contraindicated following the ingestion of phenol. This is due to the chemical's corrosive nature, the rapid onset of CNS depression and seizures, and the anesthetic effect it has on the gastric mucosa, which often makes emetics ineffective. Gastric lavage utilizing activated charcoal, olive oil, or castor oil is historically recommended to safely bind and remove the unabsorbed poison.

Dermal Decontamination: The decontamination of phenol skin burns requires specific protocols because flushing the skin with small amounts of water can exacerbate the injury by diluting the phenol and expanding the surface area of absorption. While copious, high-flow water irrigation can eventually be effective, experimental and clinical evidence strongly supports the use of low-molecular-weight polyethylene glycol (PEG 300 or PEG 400) or isopropyl alcohol as the decontamination agents of choice. These solvents are highly superior to water in neutralizing phenol, preventing its systemic absorption, and reducing the severity of the chemical burns. If PEG or isopropyl alcohol are unavailable, copious amounts of high-density water showering should be used immediately. Treatment otherwise remains largely supportive, focusing on cardiovascular resuscitation, ventilatory support, management of arrhythmias (e.g., using lignocaine for ventricular fibrillation), and correcting metabolic acidosis. While hemodialysis is generally considered ineffective for clearing phenol itself, it may become necessary to manage the subsequent acute renal failure and fluid overload.

The Superiority of Application Based Learning: The finding that over 74% of students demonstrated improved clinical reasoning through application-based learning strongly aligns with the pedagogical principle of "authentic learning." As noted in educational literature, authentic learning immerses students in activities and assignments that directly mirror how they will think and work in the "real world".[17] In the context of toxicology, merely memorizing that phenol is a protoplasmic poison is insufficient. Application-based scenarios force trainees to practice high stakes clinical decision making, such as immediately identifying unique diagnostic clues like "carboluria" (dark green, brown, or black urine). Furthermore, it tests their ability to select the correct, evidence-based decontamination fluids such as low molecular weight polyethylene glycol (PEG) or isopropyl alcohol over standard water irrigation. Since most medical trainees are preparing to be frontline practitioners rather than academic researchers, learning that replicates actual emergency execution is highly effective.

The Limitations of Traditional Teaching: The results demonstrating that traditional "teaching as talking" (e.g., standard lectures and video lectures) was insufficient for developing practical comprehension highlight a common pedagogical pitfall. This failure often occurs when instructors conflate the mere presentation of content with actual student learning. Relying solely on traditional lectures frequently stems from a lack of Pedagogical Content Knowledge and the replication of inherited teaching practices. Furthermore, traditional lectures falsely assume that students already understand how complex disciplinary knowledge such as the nuanced pharmacokinetics and rapid systemic absorption of phenol is organized and applied. Without active processing, learners fail to translate theory into action, such as recognizing the strict contraindications for emesis in acute phenol ingestion due to the rapid risk of central nervous system depression and seizures.

V. CONCLUSION

The findings of this 45-participant observational study demonstrate that integrating application based questions into the toxicology curriculum significantly enhances learners' comprehension and practical clinical readiness for managing acute phenol poisoning. With over 74% of participants showing

improved clinical reasoning, it is evident that authentic, application-based learning environments are vastly superior to traditional "teaching as talking" methods. Problem based and application based learning modalities are highly effective at promoting integrated teaching, problem solving, critical thinking, and the management of real life clinical situations.

While traditional didactic lectures may be an efficient way to present foundational information, using them as the sole mode of instruction fails to encourage the deep learning and active clinical reasoning required for complex medical emergencies. Active learning strategies, like Problem-Based Learning (PBL) foster an environment that successfully links theoretical subject matter directly to practical patient management and clinical application.

Therefore, to effectively bridge the gap between basic toxicological theory and practical clinical execution, medical education and toxicology curricula must prioritize authentic, application-based learning. By immersing students in realistic, time-critical toxicological scenarios, educators can ensure that future physicians possess the diagnostic vigilance, confidence, and procedural readiness necessary to save lives in rare but fatal emergencies like acute phenol toxicity.

Table 1 Application Based Questions

Question	Task	Answer key
Clinical Diagnosis and Management Scenario: A 25-year-old presents to the emergency department 30 minutes after intentionally ingesting a cleaning solution. The patient has a sweet, phenolic odor on his breath and a grayish-white slough over the lips and oral mucosa. Surprisingly, the patient reports a lack of severe burning pain in the mouth, complaining instead of numbness and tingling.	A) Identify the likely poison and explain why the patient is experiencing numbness instead of intense pain. B) Unlike poisoning with strong mineral acids (like sulfuric acid), what specific gastric decontamination procedure is permissible in this case, and what substances should be used?	A) Carbolic acid. The numbness occurs because phenol acts as a local anesthetic, causing an initial tingling followed by anesthesia of the tissues. B) Gastric lavage is permissible and should be performed cautiously using warm water containing charcoal, olive oil, or magnesium sulphate. Emetics have little role.
Diagnostic Markers in Urine Scenario: A patient is admitted with suspected organic acid poisoning. The nursing staff notes that the patient's freshly voided urine appears normal at first but turns a dark, smoky green color after being left exposed to the air.	A) What is the specific clinical term for this urinary finding? B) Explain the mechanism behind this color change.	A) The condition is called carboluria. B) The color change occurs because the absorbed phenol and its metabolites undergo oxidation upon exposure to air, turning the urine a dark, smoky green.
Chronic Exposure and Systemic Signs Scenario: A factory worker with chronic, low-level occupational exposure to a volatile liquid presents with a peculiar bluish-black discoloration affecting the cartilage of his ears and the sclera of his eyes.	A) What is the medical term for this specific tissue discoloration? B) Besides phenol, name two other substances or conditions that can produce this identical clinical sign.	A) The condition is known as ochronosis. B) It can also be seen in the autosomal recessive disorder alkaptonuria (due to homogentisic acid oxidase deficiency) or following exposure to substances like hydroquinone, resorcinol, picric acid, mercury, or antimalarial drugs.
Autopsy and Forensic Pathology Scenario: A forensic pathologist is conducting an autopsy on a victim who	A) What is the classic forensic term used to describe this characteristic stomach finding?	A) This is classically described as a "leathery stomach".

died 4 hours after ingesting a poison. Upon external examination, putrefaction appears unusually delayed. Internally, the stomach wall is distinctly hardened and thickened.	B) According to standard autopsy protocol for this specific poison, which body cavity should the pathologist open first, and why?	B) The cranial cavity (skull) should be opened first. This is because the distinct odor of phenol is best appreciated in the brain tissue before the strongly odorous putrefactive gases from the abdomen are released and mask the smell.
Mechanism of Action and Cause of Death Scenario: A student argues that because phenol is classified alongside mineral acids as a corrosive, its primary fatal mechanism is strictly local tissue destruction and gastric perforation.	A) Correct this student's misconception by explaining the dual action (local and remote) of carbolic acid. B) What is the most common cause of death and the typical fatal period for this poison?	A) While phenol does have a local corrosive effect (causing coagulative necrosis and grayish slough), its lethality is primarily due to its remote systemic action. Once absorbed, it acts as a powerful CNS depressant, specifically paralyzing the respiratory and cardiovascular (CVS) centres. B) The cause of death is usually respiratory failure or cardiovascular collapse due to this CNS depression. The typical fatal period is very rapid, usually 3 to 4 hours after ingestion.

Table 2 Comparative Efficacy of Teaching Methodologies

Teaching Methodology	Efficacy/ Understanding	Evaluation method
Application Based Learning	74.19% (23 out of 31 students) Understanding: High	Term ending theory and practical exam
Traditional Teaching (Lectures & Video Lectures)	28.57% (4 out of 14 students) Understanding: Low	

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