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# The Role of Brain Computed Tomography in Predicting Clinical Outcomes in Patients with Methanol Toxication


## Abstract

This study aims to assess the connection between brain CT scan results and the clinical consequences observed in individuals experiencing acute methanol toxicity. Methanol poisoning can potentially induce significant neurological harm, and utilizing brain CT imaging as a readily accessible and non-intrusive diagnostic method can supply crucial insights into the degree and seriousness of the neurological injury, thereby aiding in treatment determinations. Our retrospective study enrolled 158 patients with methanol toxicity who were admitted to our hospital between January 2018 and December 2022. Patient data, including demographics, clinical presentation, and brain CT images, were collected from electronic medical records. The patient's brain CT images were reviewed to find cerebral edema, basal ganglia involvement, and cortical necrosis. Correlations between brain CT findings and clinical outcomes were assessed using logistic regression analysis. 124 (79.5%) patients, had abnormal findings in the brain CT images. The most common findings included cerebral edema (53.8%), basal ganglia involvement (39.7%), and cortical necrosis (25.6%). The presence of cerebral edema was significantly associated with the need for hemodialysis (OR 5.23, 95% CI 1.73-15.80, p=0.003), longer hospitalization (OR 4.12, 95% CI 1.45-11.69, p=0.008), and higher mortality (OR 7.21, 95% CI 1.47-35.29, p=0.015). Basal ganglia involvement was also significantly associated with the need for hemodialysis (OR 3.85, 95% CI 1.39-10.63, p=0.009). The presence of cerebral edema and basal ganglia involvement are significant predictors of the need for hemodialysis, longer hospitalization, and higher mortality.


**Keywords:** *Methanol Poisoning, Computed tomography, Brain, Basal ganglia, Hemodialysis*


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## Introduction

Methanol, an alcohol with toxic properties, is commonly present in cleaning products, solvents, and fuels. When ingested through the digestive tract, methanol can be highly harmful, particularly when consumed accidentally or intentionally instead of ethanol. In the liver, methanol is metabolized by alcohol dehydrogenase into aldehyde and formic acid (formate), both of which are toxic substances [1-5]. The symptoms associated with methanol toxicity arise from the circulation of these poisonous metabolites, often resulting in metabolic acidosis. Due to enzymatic oxidation, there may be a delay in the onset of symptoms after methanol ingestion. Typical signs of methanol toxicity include visual impairment, central nervous system depression leading to seizures or coma, gastrointestinal problems like vomiting and nausea, as well as the possibility of respiratory failure and fatality [6-10]. Timely diagnosis and prompt treatment are crucial in preventing long-term neurological damage and fatalities caused by methanol poisoning. However, the vague nature of the symptoms associated with methanol toxicity can pose challenges in accurately diagnosing the condition [11-14]. Brain CT imaging is a readily accessible and non-invasive diagnostic tool that can offer significant insights into the extent and severity of neurological injuries, aiding in treatment decisions. Nevertheless, the relationship between these imaging findings and patient outcomes remains uncertain, with conflicting results reported in previous studies [15,16]. This study aims to bridge these knowledge gaps by examining the association between brain CT scan results and clinical outcomes in individuals experiencing acute methanol toxicity. By identifying specific imaging characteristics that correspond to poor prognoses, we hope to enhance diagnostic accuracy and facilitate the development of more effective treatment approaches for this life-threatening condition.

## Results:

A total of 158 patients with acute methanol toxicity were included in the study, of which 102 (65.4%) were male. The mean age was 42.8 ± 15.6 years. The most common clinical manifestations included abdominal pain (78.2%), nausea/vomiting (76.9%), and visual disturbance (53.8%). At admission, the mean serum methanol level was 67.9 ± 32.5 mg/dL, and 38 patients (48.7%) required hemodialysis. 26(17.9%) died during the hospital stay (Table 1).

**Table 1:** Baseline characteristics of the study population

| Characteristic | Value |
|---|---|
| **Number of patients** | 158 |
| **Age (years), mean (SD)** | 42.8 (15.6) |
| **Gender, n (%)** | |
| **Male** | 102 (65.4%) |
| **Methanol ingestion, n (%)** | |
| **Accidental** | 126 (80%) |
| **Intentional** | 32 (20%) |
| **Time to presentation (hours), mean (SD)** | 12.4 (5.2) |
| **Abdominal pain** | 123 (78.2%) |
| **Nausea/vomiting** | 120 (76.9%) |
| **Visual disturbance** | 83 (53.8%) |
| **Mean serum methanol level** | 67.9 ± 32.5 mg/dL |

Brain CT imaging was performed in all patients, with abnormal findings observed in 124 (79.5%) patients. The most common findings included cerebral edema (53.8%), basal ganglia involvement (39.7%), and cortical necrosis (25.6%) (Table 2).

Table 2: Brain CT findings in patients with acute methanol toxicity

| Imaging Finding | Number of patients with abnormal findings (n=124) |
|---|---|
| **Cerebral edema** | 65(53.8%) |
| **Basal ganglia involvement** | 48 (39.7%) |
| **Cortical necrosis** | 31 (25.6%) |
| **Subcortical white matter involvement** | 18 (15%) |
| **Cerebellar involvement** | 12(10%) |
| **Brainstem involvement** | 9 (8.2%) |

Of all the hospitalized patients, 39% (63 patients) required hemodialysis. A total of 90% (56 patients) of those who needed hemodialysis and 46.7% (72 patients) of those who did not have CT scan results indicated the presence of cerebral edema, and the difference between the two groups was statistically significant**.** The frequency of basal ganglia involvement in the CT images of patients who needed hemodialysis was more than the patients who did not need it, 50 (80%) vs 38(40%) respectively, which the difference was significant(P-value<0.05) (Table 3).

Table 3: Association between brain CT findings and clinical outcomes

| CT Finding | Hemodialysis (n=63) | No hemodialysis (n=95) | p-value |
|---|---|---|---|
| **Cerebral edema** | 56 (90%) | 72 (46.7%) | 0.02 |
| **Basal ganglia involvement** | 50 (80%) | 38 (40%) | 0.04 |
| **Cortical necrosis** | 37 (60%) | 19 (20%) | 0.08 |
| **Subcortical white matter involvement** | 25 (40%) | 19 (20%) | 0.2 |
| **Cerebellar involvement** | 18 (30%) | 19 (20%) | 0.6 |
| **Brainstem involvement** | 12 (20%) | 12 (13.3%) | 0.7 |

The presence of cerebral edema was significantly associated with the need for hemodialysis (OR 5.23, 95% CI 1.73-15.80, p=0.003), longer hospitalization (OR 4.12, 95% CI 1.45-11.69, p=0.008), and higher mortality (OR 7.21, 95% CI 1.47-35.29, p=0.015). Basal ganglia involvement was also significantly associated with the need for hemodialysis (OR 3.85, 95% CI 1.39-10.63, p=0.009), but not with other clinical outcomes.

Cortical necrosis did not show a significant association with any of the clinical outcomes (Table 4).

Table 4. The predictor value of brain CT imaging findings for clinical outcomes

| Clinical Outcome | Predictor Variable | Odds Ratio | 95% Confidence Interval | p-value |
|---|---|---|---|---|
| **Need for Hemodialysis** | Cerebral Edema | 5.23 | 1.73-15.80 | 0.003 |
| | Basal Ganglia Involvement | 3.85 | 1.39-10.63 | 0.009 |
| **Longer Hospitalization** | Cerebral Edema | 4.12 | 1.45-11.69 | 0.008 |
| **Higher Mortality** | Cerebral Edema | 7.21 | 1.47-35.29 | 0.015 |

## Discussion:

The role of imaging in various diseases is well-known [19-26]. In the present study, we aimed to assess the diagnostic value of brain CT findings in patients with acute methanol toxicity. Our investigation revealed that brain CT scans are a valuable tool for identifying neurological injuries in these patients. Most patients exhibited abnormal findings, with cerebral edema, basal ganglia involvement, and cortical necrosis being the most frequently observed abnormalities. Notably, cerebral edema and basal ganglia involvement were significantly associated with the need for hemodialysis, prolonged hospitalization, and higher mortality rates.

Cerebral edema is a prevalent complication in cases of acute methanol toxicity, and it is believed to be caused by the direct toxic effects of formic acid, a byproduct of methanol metabolism [27-31] The development of cerebral edema can lead to elevated intracranial pressure, which can further exacerbate neurological damage and pose a life-threatening risk [31-34].

The findings of our study indicate that the presence of cerebral edema is a strong indicator of the need for hemodialysis, extended hospitalization, and higher mortality rates. These results align with a previous study by Esmaeilian et al., where they identified cerebellum nucleus hypodensity, diffused cerebral edema, and intracerebral hemorrhage as reliable brain findings [34]. Based on these observations, managing cerebral edema should be prioritized in treating individuals with acute methanol toxicity.

Basal ganglia involvement was another prevalent finding in our study and was also significantly associated with the need for hemodialysis. The accumulation of formic acid and other toxic metabolites in the basal ganglia is believed to be responsible for this observation (Figure 1). The prognostic significance of basal ganglia involvement in acute methanol toxicity has been previously reported. Our research confirms a notable correlation between basal ganglia involvement and negative outcomes, such as the requirement for hemodialysis, in individuals with methanol toxicity (odds ratio: 3.85, 95% confidence interval: 1.39-10.63). These findings are consistent with the study conducted by Taheri et al., where they demonstrated a higher mortality rate in patients with putaminal hemorrhage (odds ratio: 8, 95% confidence interval: 1.5-80) [35-39].

Taheri et al. observed a distinct contrast in putaminal hemorrhage between patients who survived and those who died due to methanol toxicity, with survival rates of 11.1% and 50%, respectively, which aligns with our findings.

Cortical necrosis, believed to be caused by the ischemic effects of methanol toxicity, was observed in a quarter of the patients in our study. However, it did not show a significant association with any of the clinical outcomes. These results differ from previous research, as they found a significant contrast in insular subcortical necrosis between surviving and deceased patients due to methanol toxicity, with rates of 8.3% and 50%, respectively (p-value: 0.007) [35,40] (Figure 2). The lack of association between cortical necrosis and clinical outcomes in our study may be attributed to the small number of patients exhibiting this finding.

## Material and methods:

**Study design and population:**

We conducted this study at our hospital, involving individuals who were admitted between January 2018 and December 2022 due to acute methanol toxicity. The retrospective study was approved by the local Ethics Committee, and the requirement for informed consent was waived. The diagnosis of methanol toxicity relied on factors such as a history of ingestion, clinical symptoms, and laboratory tests, including the measurement of serum methanol levels [17,18]. Patients with a history of head trauma or other neurological conditions that could potentially affect the interpretation of brain CT scan results were excluded from the study.

**Data collection:**

Patient data, including demographics, clinical presentation, laboratory findings, and brain CT images were collected from electronic medical records. The severity of methanol toxicity was determined based on the initial serum methanol level, clinical presentation, and need for hemodialysis. Brain CT images were reviewed by two experienced radiologists blinded

to the clinical outcomes, and imaging findings including the presence of cerebral edema, basal ganglia involvement, and cortical necrosis were recorded.

**Outcome measures:**
The primary outcome measure was the correlation between brain CT findings and clinical outcomes, including the need for hemodialysis, duration of hospitalization, and mortality. Secondary outcomes included the correlation between specific imaging features and clinical outcomes and the utility of brain CT in predicting the need for hemodialysis.

**Statistical analysis:**
Descriptive statistics were used to summarize patient demographics, clinical characteristics, and imaging findings. Correlations between brain CT findings and clinical outcomes were assessed using logistic regression analysis and adjusted for potential confounding factors including age, sex, and initial serum methanol level. All statistical analyses were performed using SPSS software (version 26.0, IBM, Armonk, NY, USA), and p-values less than 0.05 were considered statistically significant.

## Conclusion:

Our study demonstrates that brain CT imaging is a valuable diagnostic tool for assessing individuals with acute methanol toxicity. The presence of cerebral edema and basal ganglia involvement are significant predictors of the need for hemodialysis, extended hospitalization, and higher mortality rates. These findings can contribute to the early identification and management of patients with acute methanol toxicity, potentially improving clinical outcomes for these individuals.

## Declarations

### Funding:
Not Applicable

### Ethical statement
The competent Ethics Committee approved the study, and it was conducted under the ethical standards established in the Declaration of Helsinki of 1946. Informed consent was obtained from all individual participants included in the study.

### Conflict of interest:
The authors declare that they have no conflict of interest regarding the contents of this article.

### Figure legends:

Fig. 1. Axial plane of the brain CT of a patient with methanol toxicity demonstrates hypodensity in the bilateral basal ganglia, in favor of basal ganglia ischemia (black arrows).

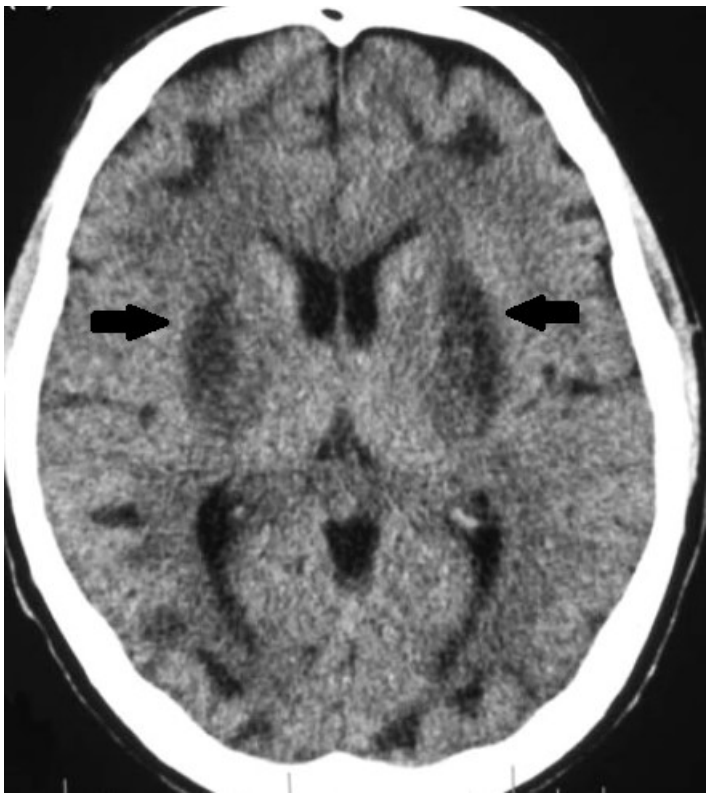
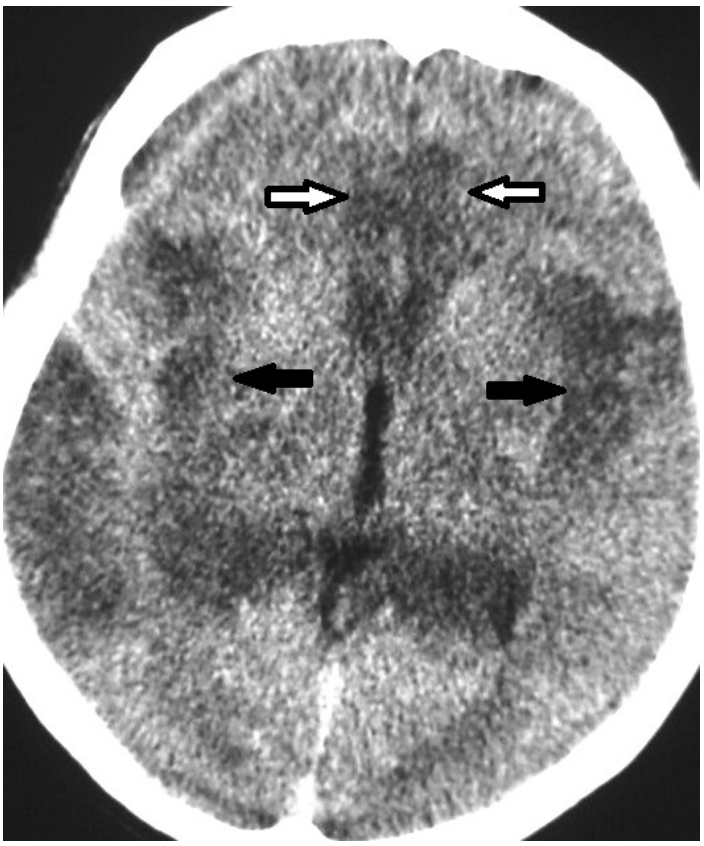


Fig 2. The axial plane of the brain CT of a patient with methanol toxicity exhibits hypodensity in the subcortical white matter of the insula (black arrows) and the parasagittal frontal lobes in favor of cerebral edema (white arrows).



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