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Petroleum Intoxication: Literature Review and Case Report on Poisoning by Gasoline

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SUMMARY
A literature review of cases of acute poisoning by petroleum and its distillates was conducted, while a new fatal case of suicide by gasoline intake is reported. Specifically, a number of studies were reviewed in order to update and summarize the relevant literature on the incidence, sociodemographic variables, method of poisoning, diagnostic - toxicological procedures, variables associated with survival and fatality on acute petroleum/gasoline intoxication. Results show that acute poisoning by petroleum and its distillates is relatively rare. Male prevalence was observed among patients, while most incidents were classified as suicide attempts. Oral ingestion was the most frequent method of intake, while a case of intravenous injection was also reported. The survival rates were low, as among all literature cases, two thirds of them managed to reach the hospital alive, and only the one fourth of them had a medically successful outcome.

Keywords: forensic pathology – forensic science – acute – intoxication – poisoning – suicide – petroleum – gasoline

Otravy ropnými produkty: rešerše literatury a kazuistika - otrava benzínem

SOUHRN
Autoři provedli rešerši literatury zabývající se případy akutní otravy ropnými produkty a zároveň popsali nový smrtelný případ sebevraždy požitím benzínu. Konkrétně byla přezkoumána řada studií s cílem aktualizovat a shrnout příslušnou literaturu týkající se výskytu, sociodemografických ukazatelů, způsobů otrav, diagnosticko-toxikologických postupů, faktorů souvisejících s přežitím a úmrtností při akutní intoxikaci ropou/benzínem. Výsledky ukazují, že akutní otrava ropou a jejími produkty je relativně vzácná. Mezi pacienty byla pozorována prevalence mužů a většina případů byla klasifikována jako pokusy o sebevraždu. Nejčastějším způsobem otravy bylo orální požití, avšak byl zaznamenán i případ intravenózní injekce. Míra přežití byla nízká, ze všech literárně uváděných případů se dvě třetiny intoxikovaných podařilo transportovat do nemocnice, ale pouze čtvrtinu z nich se podařilo zachránit.

Klíčová slova: soudní lékařství – forenzní vědy – akutní – otrava – sebevražda – ropa – benzín

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History

The word petroleum is derived from the word "petra" which in Ancient Greek means rock and "oleum" which is the Latin word for oil. (1,2) The first use of this term dates back to the 10th century and in later times it was used to describe mineral oils. Its use is dated back to ancient China and it is mentioned in "The book of changes." At first, it was used without distillation, in its unprocessed form. In more recent times, however, it is refined and used to synthesize a wide variety of every-day materials including plastics and fertilizers. Today petroleum is an integral part of economy, mainly due to its industrial as well as its commercial use. (3-9) Petroleum products are common goods used mainly for household needs such as cooking and heating, industrial needs, lubricants, cleaning products, cosmetics, and fuels for motor vehicles as well as aviation. A variety of products is made in refineries, which are available to everyone.

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Formation and composition

Petroleum is a naturally occurring, yellowish-to-black liquid located in geological formations in the subsoil, comprising hydrocarbons in liquid, solid and gas form. The composition and form of petroleum varies depending to the conditions it is in. In temperatures and pressures of the surface, hydrocarbons with heavier weight tend to be in solid or liquid forms, while lighter ones are gaseous. (10-12)

In order for petroleum to be formed, organic material has to be fossilized; algae for instance. The formation occurs when hydrocarbons and specific minerals combine under conditions of extreme pressure, mainly in the sea bottom mixed with sand and silt. Due to the lack of oxygen, the organic material is not able to fully decompose aerobically, and in this way, the raw materials needed for petroleum formation are produced. Endothermic reactions take place either in high temperatures or in high pressure. (13-20) These reactions include the (a.) first phase of diagenesis when anaerobic decay occurs, (b.) second phase of diagenesis when kerogen is formed, and (c.) catagenesis when kerogen is transformed into fossil fuels. (18)

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Chemistry

Crude oil mainly consists of cycloalkanes (approximately 45%), aromatic hydrocarbons (approximately 15%), and alkanes (approximately 30%). The molecular composition of crude oil is unstable and there is a wide variety between formations. The elements involved are limited, however, with carbon and hydrogen being the most common, while nitrogen and oxygen follow in decreasing order. (10-12)

Cycloalkanes or naphthenes are saturated hydrocarbons. These molecules are monocyclic and consist only of hydrogen and carbon. All carbon-carbon bonds are single, and it is possible that side chains are present. The formula for cycloalkanes is $C_nH_{2(n+1-f)}$. (15,16)

Furthermore, alkanes are also saturated hydrocarbons. They are acyclic and consist of hydrogen and carbon atoms arranged in a tree-like structure in which all the carbon-carbon bonds are single. These molecules range from 5 to 40 carbon atoms and their general formula is C_nH_{2n+2}. Molecules from 5 to 8 carbon atoms are refined into gasoline (e.g. pentane), those from 9 to 16 atoms of carbon into kerosene, diesel and jet fuel while those with more than 16 can be used in order to produce fuel oil. Some alkanes can have even more carbon atoms, like paraffin wax with 25 or asphalt with 35. (17,18)

On the other hand, aromatic hydrocarbons are unsaturated and contain a benzene ring. Their formula is C_nH_{2n-6}. (17,18)

Medicinal use

A partially solid mix of hydrocarbons with more than 25 atoms of carbon named petroleum jelly has been used as a topical treatment for a wide variety of ailments as well as cosmetic purposes, including fungal nail infections, skin and genital rashes, nosebleeds, diaper rash, and chest colds. Nowadays, it is an FDA-approved over the counter medication. Its usage has been proposed by The American Academy of Dermatology mostly for the prevention of scarring of dehydrated tissue in the post-operative period after laser skin operative treatment. (21-24)

METHODOLOGY

The purpose of the present paper is to synopsize all available information on poisoning due to ingestion of petroleum and its distillates and report a case of suicide by gasoline intake in a 57-year-old male. The authors have summarized the results of the systematic review they performed using the electronic database of PUBMED as well as Google search/scholar and Scopus up to April of 2018. The search terms used were: "Gasoline suicide", "Gasoline poisoning", "Petroleum ingestion", "Petroleum", "Gasoline ingestion," "Gasoline intoxication," "Petroleum intoxication." No language restriction was applied. Case reports with inadequate clinical histories were opted to be excluded. Moreover, all articles have been supplemented by research of key references in order to establish the incidence, method of poisoning, sociodemographic status of patients, clinical course, prognosis, and outcomes of gasoline poisoning.

CASE PRESENTATION

A 57-year old male presented to the emergency room with nausea, vomiting and mediastinal -epigastric pain after a suicide attempt with gasoline (2-3 L). His blood pressure was 110/80 mmHg and heart rate 100 beats per minute. The arterial blood gas examination indicated metabolic acidosis with pH = 7.20; pO_2 = 99 mmHg; pCO_2 = 17 mmHg; lactates >15 mmol/L; bicarbonate = 6.6 mmol/L. In addition, blood test results disclosed elevated white blood cell count (WBC).

Instructions provided by the National Poison Center were followed. Esomeprazole, saline solution and bicarbonate were administered to the patient, and his condition was stabilized. Subsequently the patient was admitted to the Intensive Care Unit for further monitoring.

His personal history was extracted by his past medical records, which revealed that the patient was also suffering from coronary disease for which he had also underwent angioplasty and stent placement, had a history of pulmonary embolism, and was also diagnosed with unipolar major depressive disorder with psychotic features.

During six days of hospitalization, the patient's condition gradually deteriorated. His white blood cell count (WBC), blood urea nitrogen (BUN), serum creatinine (SCr), hepatic enzymes, lactate dehydrogenase (LDH), alkaline phosphatase (ALP), and prothrombin time (PT) levels were increasing, while thrombocytopenia (low platelet count) and anemia (low hemoglobin, hematocrit, and red cell count) began developing. The latest results from the Intensive Care Unit Department before the patient's death indicated multiple organ dysfunction syndrome (MODS) and endoscopic evaluation (gastroscopy) was urgently performed, which revealed upper gastrointestinal bleeding with multiple hematomas.

RESULTS

Autopsy findings

Postmortem examination revealed brain edema, pulmonary edema, gastric erosions, atheromatous degeneration of the aorta and coronary arteries, and myocardial signs of past myocardial infarction. Autopsy findings indicated that the cause of death was brain edema and cardiac arrest, provoked by hepatorenal dysfunction triggered by the petroleum intake leading to cardiopulmonary insufficiency due to cardiac overload (hypervolemia). Evidence supported the diagnosis of multiple organ dysfunction syndrome, but tissue samples collected from the brain, myocardium, lungs, stomach, liver, spleen and kidneys were dispatched for histopathological examination so that the diagnosis be confirmed and documented at a microscopic level as well.

Histopathological results

The histopathological examination reported partial degeneration of brain cells, liver and spleen necrosis, myocardial interstitial edema and fibrosis, pulmonary edema, necrosis and partial fibrosis, as well as partial kidney necrosis. More specifically, in most of the tissue samples, bleeding infiltrates, foci with autolytic and necrotic features, inflammatory infiltrates, phagocytes, hemosiderin granules and congestive vascular alterations of varying degrees were found.

In the cerebral tissue specimen, the histopathological examination disclosed partial destruction of the brain substance, degenerated cells, cells with eosinophilic cytoplasm and thickened nucleuses, as well as capillary vessels with congestive vascular alterations.

In the tissue specimens of the myocardium, recent and older ulcerations of ischemic type were detected as well as interstitial edema, extensive fibrosis, and numerous areas of connective tissue presence (extensive areas of necrosis). Myocardial fibers exhibited corrugated morphology and disarrayed layout. Localized hemorrhagic, fatty and inflammatory infiltrations were also detected, as well as arteriolar wall thickening and the presence of red blood cells in varying degrees.

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In the pulmonary tissue samples, extensive hemorrhagic infiltrates, edema, presence of eosinophilic material in alveoli and bronchioles was noted, as well as bronchial / alveolar destruction sites (in the bronchioles presence of fibrin gland, red blood cells, inflammatory summations, cellular debris and cell degeneration / necrosis was observed to varying degrees), and fibrosis foci. Additionally, areas with necrotic foci, emphysematous lesions, inflammatory infiltration sites, several phagocytes, hemosiderin granules, and foci of carbonization were identified, as well as varyingly congested arterioles with wall thickening, and with the presence of red blood clots of varying degrees in the lumen in several of them.

In the tissue specimen of the inner stomach wall, the histopathological examination revealed autolytic features, hemorrhagic infiltrations, sites with corrosive lesions / mucosal micro-ulcerations - in a few sites with relatively deeper extension, while areas were identified with a relative elongation of the gastric sinuses / relative muscle cell hyperplasia, edematous corneal looseness, presence of inflammatory summations and variously congested vessels.

In the tissue specimen of the liver, the histopathological examination revealed distended liver sinusoids, necrotic sites, autolytic features, sites of hemorrhagic and inflammatory infiltration, as well as severe fatty hepatocyte degeneration of hepatocytes.

In the tissue specimen of the spleen, the histopathological examination revealed distended Billroth cords, sites of hemorrhagic infiltration, necrotic foci, sites with phagocytes, hemosiderin granules, and vessels with the presence of red blood clots of varying degrees.

In the tissue specimen of the renal parenchyma, the histopathological examination revealed the presence of eosinophilic content in glomeruli / renal tubules in several sites, vitrification sites, sites of hemorrhagic infiltration, autolytic and necrotic foci, inflammatory infiltration sites, phagocytes, hemosiderin granules and variedly congested vessels.

Incidence

The incidence of petroleum poisoning is low and intoxication can be caused either accidentally or intentionally, leading, in turn, to conditions that range in severity from asymptomatic to fatal. According to the American Association of Poison Control, petroleum is not included in the ten most common substances to cause poisoning, even when children are concerned. (25) However, a study performed over 10 years in the US analyzed hydrocarbon poisoning cases in children revealing gasoline to be the most common cause with more than 12,000 cases over that period. The effects in such cases can be pulmonary, gastrointestinal, ocular, cardiac, dermal, hematologic or renal, accordingly to the exposure pathway. Treatment is symptomatic, as no antidote is available. (26)

Method of intake

Among adult individuals, the most common way for unintentional hydrocarbon poisoning is siphoning off gasoline, which is able to induce pneumonia if the substance enters the lungs. (27,31,32) On the other hand, cases have also been reported associated with intentional intake of hydrocarbon-related products in the context of self-destructive actions due to active suicidal ideation, either through intravenous injection or through ingestion.

Demographics

Most of the presented cases involved males (83.3%), and were classified as suicide attempts (41.7%). Furthermore, the most common method of intake was oral ingestion (66.7%). In the majority of cases the outcome was fatal (75%) and in numerous cases, patients were already deceased at the time that they were detected (25%). Among all literature cases, eight managed to reach the hospital (66.7%), and only three of them managed to be administered with a successful treatment (25%). Furthermore, among the aforementioned non-fatal cases, only two managed to get a full recovery (16.7%), while the other one was left with permanent damage and had to undergo liver transplantation. (Table 1) (28-45) It is highlighted that there are limitations in the above-mentioned statistical data, as they are extracted from an extremely limited sample of cases (N=12).

DISCUSSION

In regard to the incident described in the present work, similarities can be identified in comparison with bibliographic data, as a male individual involved who committed suicide by oral ingestion of gasoline was already diagnosed as a psychiatric patient. Hospitalization duration was less than a week, while the outcome was fatal due to multiple organ dysfunction syndrome.

The marked difference between the two sexes (M:F; 5:1) can be attributed to the fact that males choose more violent suicide methods of higher lethality in comparison to women. (46-48) In addition, males are more likely to be exposed to gasoline or petroleum derivatives by accident, as they are more often associated with manual labor in contrast to females.

Clinical manifestations and mechanism of toxicity

Although petroleum and its by-products, such as diesel and gasoline, are widely used, there is little empirical information reported throughout international literature about its toxicity and effects on the human body. Furthermore, cases of ingestion of products like kerosene or gasoline in the context of self-harm are very scarce. (28-30,49-52)

Fink et al. reported a case of suicide attempt by petroleum injection that presented with severe soft-tissue inflammation. Even though surgery was performed in the affected area, the skin condition reoccurred due to tissue necrosis. Domej et al. also reported a case of gasoline suicide attempt that presented with severe respiratory symptoms, but resulted in a total recovery after 12 days. Other studies, such as the case reported by Verma et al. mentioned the occurrence of severe pneumothorax caused by gasoline intake that required surgical intervention. (28-30)

Murine studies also indicated that petroleum induced the enzymatic activity of the Hepatic Palmitoyl-CoA Oxidase, thus leading to peroxisomal proliferation in the liver of mice. (50,51)

As mentioned before, the harmful effect of petroleum and its by-products is caused mainly due to hydrocarbons and their physical properties (including their volatility, viscosity, surface tension), as well as chemical activity of the side-chains. The symptomatology that is induced after the intake of these products can affect numerous organs and systems of the human body, including the respiratory system, intestinal tract, nervous system and skin, as well as manifestation of blood disorders.

The respiratory system is primarily affected by direct injury, and thus, severe necrotizing chemical pneumonitis is often the major pathological finding in cases of petroleum poisoning, induced by low surface tension, low viscosity, and the solvent properties that aspirated hydrocarbons exhibit. The airway epithelium, pulmonary capillaries and alveolar septa undergo direct damage and the lipid surfactant layer is solubilised, while interstitial inflammation, atelectasis, and hyaline membrane

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Table 1. Poisoning cases with petroleum or gasoline reported in literature.

N	Age / Gender	Medical history	Manner of poisoning	Method of intake	Time until ER admission	Findings/ Symptomatology	Treatment administered	Hospitalization/ Outcome	Reference
1.	70/M	Unspecified psychotic disorder - Hypertension	Suicide	Oral ingestion of unleaded gasoline	Not disclosed	Severe level of consciousness impairment GLS 8; severe aspiration pneumonia; manganese neurotoxicity	Gastric lavage – Activated charcoal – Transferred in ICU	3 weeks / Expired	(34)
2.	86/M	Onset of depressive episode 15 days prior to the incident. Hiatal hernia, chronic gastritis, 3rd degree atrioventricular block, hypertension, benign prostatic hyperplasia	Suicide	Oral ingestion of diesel fuel and hanging	Found dead		–	Expired	(40)
3.	64/F	No history	Suicide	Oral ingestion of diesel fuel	Not disclosed	Gastric perforation, peritonitis.	Morphine and Midazolam	18 hours / Expired	(39)
4.	22/M	Asperger's syndrome and past suicide attempt	Suicide	Intravenous injection of gasoline	2 hours	Bradycardia, hypotension, Type 1 respiratory failure – diffuse alveolar-toxic damage to lungs, soft-tissue phlegmon	Clindamycin, ceftriaxone, metronidazole and anticoagulants	3 weeks / Recovered	(31)
5.	26/M	No history	Suicide	Intravenous injection of gasoline 10mL	–	Hemoptysis, symptoms of acute respiratory failure, chest pain, and severe abdominal cramps, chemical pneumonitis, multi-organ dysfunction syndrome (MODS), severe vasoplegia, acute renal failure	Mechanical ventilation, nitrogen oxide, prednisone, vasopressors, hemofiltration for 5 sequential days	12 days / Recovered	(38)
6.	58/M	No diagnosis - 2 weeks' history of another gasoline intake	Pleasure	Oral Ingestion of gasoline drink mixed with cola	–		Fluid replacement and hemodialysis	Expired	(37)
7.	73/F	Senile dementia	Accidental	Oral Ingestion of petroleum smelling liquid	Found dead		-	Expired	(36)
8.	26/M	No history	Accidental	Inhalation of gasoline	Pronounced dead upon arrival at the hospital		-	Expired	(36)
9.	15/M	History of cannabis abuse	Pleasure	Inhalation of gasoline and perhaps other solvents	Found dead		-	Expired	(36)
10.	1/M	No history	Accidental	Oral Ingestion of 10-15mL diesel	Immediately brought to the hospital		Intubation, and measures to correct the acidosis along with an antibiotic cover	3 days / Expired	(41)
11.	25/M	Four days- fever, sore throat, poor appetite, cough and shortness of breath; No other history	Occupational Malpractice	Oral Ingestion of diesel	One week		Ceftriaxone, ventilation and hemodialysis, IV methylprednisolone	23 days / Expired	(45)
12.	23/M	Two-month history of progressive yellowish discoloration of eyes, bilateral ankle swelling and abdominal distention; No other history	Occupational Malpractice	Oral Ingestion of gasoline (small amount over the course of 5 years)	–		Symptomatic treatment Ursodeoxycholic acid, spironolactone, furosemide, lactulose, and carvedilol	Gradually improved over several weeks of hospitalization – Worked up for liver transplant	(35)

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formation are secondary changes that follow (oedema and fibrosis). Chemical irritation usually precipitates inflammatory response that is expressed by temperature elevation (38-40 °C). Severe pulmonary complications may quickly progress to shock and respiratory arrest. (49,53)

Highly lipid soluble volatile hydrocarbons enter the circulation through the lungs and rapidly diffuse into the central nervous system (CNS). Neurons, which have high lipid content, are therefore particularly susceptible to severe pulmonary injury and hypoxia. Depending on the degree of exposure to hydrocarbons, CNS symptomatology may include dizziness, ataxia, lethargy, epileptic seizures, and even coma. Hydrocarbon inhalation may additionally have detrimental CNS effects due to hypoxia. (49-53)

Cardiovascular symptoms and dysrhythmias are induced by exposure to solvent hydrocarbons that sensitize the myocardium to endogenous and exogenous catecholamines. In regard to hematologic disorders, leukocytosis is the most frequent manifestation occurring shortly after exposure. On the contrary, large ingestion of petroleum and its by-products may induce hemolysis, hemoglobinuria and even consumptive coagulopathy. Gastrointestinal symptoms ranging from nausea to hematemesis are due to direct localized injury after ingestion (edema and mucosal ulceration). Hepatic and/or renal tubular necrosis (resulting into liver/renal failure respectively) may manifest secondarily to the above-mentioned manifestations after petroleum ingestion due to halogenated hydrocarbons. (49-53)

The severity and prognosis of such incidents is heavily based on the quantity of the material that has been ingested or injected into the human body as well as the duration of time having lapsed until the administration of treatment. (49,53)

Toxicological analysis

Analysis of blood for hydrocarbons is feasible but interpretation of result is difficult due to the complexity of the mixture of substances contained in petroleum fractions and therefore blood hydrocarbon concentrations have limited diagnostic, prognostic and therapeutic value. The toxicological analysis is useful if there is suspicion that another toxic substance has been co-ingested (e.g. lead). (54)

Head-Space Gas Chromatography in combination with Flame Ionization Detector or Mass Spectrometry is the proper method for the detection of volatile petroleum products. These substances are not detected within a routine drug screening. In suspicious cases of intoxication by volatile organic compounds the target analysis is applied. In fatal poisoning cases due to gasoline inhalation, volatile petroleum products can be detected if the analysis is performed within approximately 10 hours after exposure. (41) In general, the detectability of these compounds in biological samples depends on the time elapsed between exposure and samples collection and in cases of delayed deaths the toxicological analysis (performed post mortem) will be negative. (41)

In fatal poisoning cases where it was possible to determine the concentrations of the petroleum products, the following levels of the selected volatile substances were found. (Table 2)

CONCLUSION

Acute poisoning due to petroleum and its distillates, either intentional or accidental, may induce many complications that may ultimately be life-threatening due to the harmful effect of the hydrocarbons which are present in their composition. The clinical course that is induced after acute intoxication by the aforementioned substances can be pulmonary, gastrointestinal, ocular, cardiac, dermal, hematologic or renal, accordingly to the exposure pathway. Volatile substances are not detectable within a routine drug screening and therefore in suspicious circumstances the collected material is specifically examined by Head-Space Gas Chromatography in combination with Flame Ionization Detector or Mass Spectrometry – see the paragraph *Toxicological analysis* above.

In poisoning cases from gasoline there is a time "margin" during which gasoline can still be detectable.

The prognosis of such incidents is heavily based on the quantity of material that has entered the human body as well as the duration of time from the exposure to treatment administration. Treatment is symptomatic, as no antidote is available. Most of the reported cases encountered throughout relevant literature involved deliberate poisoning in which self-harm was intended mainly by male individuals with active psychopathology. Oral ingestion was the most frequent method of intake. Among literature cases, two thirds managed to reach the hospital alive, and only one fourth of them survived.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

Table 2. Blood concentrations of gasoline products in fatal cases (mg/L or µg/mL).

Conc. of benzene	Conc. of toluene	Conc. of xylene isomers	No. of cases	Route of exposure	Reference
39	24	30	1	inhalation	(42)
-	-	18, 28, 38	3	inhalation	(36)
-	-	3, 20, 122	3	ingestion	(43)
-	-	36	1	inhalation	(44)

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