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CHAPTER 14

Methyl alcohol

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The clinical presentation of methyl alcohol intoxication in humans may vary from one extreme which mimics an intracranial catastrophe to a more subtle picture which may consist only of vague constitutional symptoms and a mild visual disturbance. When many patients with similar complaints and physical findings arrive at a hospital emergency room within a short space of time, it is not difficult to infer that an intoxicant might be the responsible etiologic agent. Such a diagnosis is, however, much more difficult when one deals only with a single case. Consequently, the broad spectrum of methanol poisoning deserves the attention of neurologists.

Methyl alcohol (CH_3OH, methanol, wood alcohol) was produced initially by wood distillation and fractionation, yielding a liquid with a terrible taste and odor (Wood 1912). By 1899, production refinements had resulted in inexpensive methods of deodorizing methanol. Consequently, the alcohol rapidly became used in industry as a solvent, as well as in the manufacture of paint, rubber, synthetic textiles, linoleum, shoes and dyes. It was utilized also as a cheap substitute for ethyl (grain) alcohol for external purposes such as liniments and toiletries (Columbian spirits, bay rum, cologne water, witch hazel, standard wood spirits), as one of many adulterants used to denature (make unfit to drink) products containing ethanol, and even as an additive to products designed for ingestion (methylated Jamaica ginger, lemon extract, essence of peppermint and lemon, and various patent medicines). Despite occasional reports of serious human intoxication with methyl alcohol as early as 1855 (MacFarland 1855), vigorous denial of the poisonous character of this substance persisted until the second decade of this century. A prime reason for this was economic. In 1904 untaxed methanol cost 50c. a gallon, while taxed ethanol cost $ 2.60 per gallon (Wood and Buller 1904). Ignorance of, or ignoring, the hazardous properties of this agent, abetted by inadequate product-warning labels, finally was dispelled by Wood and Buller, who in 1904 documented 275 cases of blindness or death related to methyl alcohol usage.

At the present time, methanol-containing liquids still are used by alcoholics as cheap intoxicants or as a temporary alternative when ethanol is not available for consumption. Disasters occur when higher than expected proportions of methyl to ethyl alcohol are ingested. For example, in Kentucky an alcoholic drink called 'heads' was made from a brand of shellac thinner costing $1.95 per gallon and which contained 51.4–61.5% ethanol and 2.45–2.84% methanol, by volume (Kane et al. 1968). This was diluted 1–2 times, put into half-pint bottles and sold for a profit of 100–200%. Little apparent injury resulted from this practice but when a shellac solvent

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containing 74% methanol and 0.5% ethanol, by volume, was used inadvertently, 18 people were poisoned, eight of whom died. Other outbreaks have been reported in groups or individuals that ingested antifreeze, adulterated vodka (Tonkabony 1975) and sake, mixtures of inflammable liquids and carbonated beverages, duplicating fluid (Tonning et al. 1956), etc. The largest number of individuals reported affected at any one time has been 323, of whom 41 died, in an outbreak in Atlanta in 1953 (Bennett et al. 1953). Many persons were affected during Prohibition in the United States when the use of ethyl alcohol as a beverage was illegal and substitutes were sought. For example, 400 fatalities were recorded during one 7-month period at that time (Cooper and Kini 1962). Similar restraints on the use of ethyl alcohol in the military have resulted in many instances of poisoning with methyl alcohol. It has been estimated that 6% of all cases of blindness in the U.S. Armed Forces during World War II resulted from methanol (Potts and Johnson 1952; Cooper and Kini 1962). Lately, methyl alcohol largely has been removed from a number of products, such as antifreeze and synthetic fuels, and it is to be hoped that the incidence of poisoning will be reduced significantly.

Ingestion is not the only method of methanol poisoning, for inhalation of fumes in concentrations exceeding 200 p.p.m. in air (Bennett et al. 1953; Walsh and Hoyt 1969; Dreisbach 1974) or absorption through the skin can cause serious or fatal intoxication. Blindness has been reported in a factory worker who accidentally spilled a gallon of methanol on a trouser leg (Cooper and Kini 1962). The possibility of intoxication in infants in Argentina whose skin was rubbed with a methanol contaminated rubbing alcohol has been reported recently (Wenger 1975).

There appears to be a wide variation in the ability of individuals to tolerate the ingestion of methanol without developing toxic signs (Chew et al. 1946). Varying amounts of the alcohol are imbibed frequently by many alcoholics during the course of almost daily drinking, without evident consequences. Even so-called 'social' drinkers consume small amounts of methanol, for in one popular brand of vodka there is 3.9 mg/l of methanol, while one particular brand of bourbon has 26 mg/l and another has 40–55 mg/l (Murphree et al. 1966; Majchrowicz and Mendelson 1971). Six Russians were noted to drink 4 liters of 40% methanol without sequelae (Røe 1946), while, by contrast, blindness has resulted from the intake of as little as 4 ml in one instance (Røe 1943; Bennett et al. 1953) and two teaspoonsfull in another. In the Atlanta epidemic, 15 ml caused a fatality, while another person drank 500 ml and survived (Bennett et al. 1953). The reason for this individual susceptibility is not known, although in some cases the concomitant ingestion of ethyl alcohol may be protective, as noted below. Recently the endogenous production of methyl alcohol has been described. An enzyme which forms methanol from adenosylmethionine is present in the pituitary gland of several mammals, including man, and can be used as a marker denoting the tissue of origin of certain tumors (Snyder et al. 1967).

SYMPTOMS AND SIGNS

From the many cases described in the literature a fairly complete clinical picture of intoxication has emerged (Bennett et al. 1953; Røe 1955; Krishnamurthi et al. 1968). However, the course *in any* one patient may be highly individualized and there is no good correlation between the severity of the symptoms and the quantity of methyl alcohol consumed. Following ingestion, an asymptomatic latent period of 12–24 hours usually occurs, although transient symptoms may be noted in as short a period as 1 hour, or illness may be deferred for more than 48 hours (Cooper and Kini 1962). When symptoms and signs do appear, characteristically they involve the visual apparatus, the central nervous system (CNS), the gastrointestinal system and the respiratory tract.

Visual disturbances are noted by most patients and vary from initial complaints of a diminished sensation of light and mild photophobia to blurred or indistinct vision, often described as the perception of dancing spots, the presence of skin over the eyes, or flashes of grayish, whitish or yellow vision as in a snow storm (Chew et al. 1946; Benton and Calhoun 1952; Benton and Calhoun 1953; Bennett et al. 1953). Characteristically, the sensorium is clear at this time. Blindness, either partial or complete, develops in many

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patients who are poisoned severely and may come on within hours or develop gradually over several days or weeks. One patient developed blindness 40 minutes after ingesting half a pint of liquid containing 35–40% methanol (Bennett et al. 1953).

Examination of the visual apparatus often discloses pupils that react sluggishly or not at all to light. Even in the absence of objective evidence of visual loss, the pupils may be dilated and react poorly (Bennett et al. 1953). Accurate early assessment of visual acuity may be difficult because of the patient's mental state, the presence of exposure keratitis and mydriasis (Krolman and Pidde 1968), but in severe cases acuity may be diminished significantly. Total bilateral blindness may be present within a few hours or days. The optic nerve may be severely hyperemic but occasionally it may appear normal in a patient with severe visual loss, indicating the presence of retrobulbar neuritis (Duke-Elder 1954). Mild or severe edema of the optic disc and the surrounding retina may be noted within 6–24 hours, with the retinal edema being most extensive along the course of the major retinal vessels (Benton and Calhoun 1952). In the peripapillary region, the retinal edema is chiefly in the nerve fiber layer (Krolman and Pidde 1968). Arterial spasm is sometimes present and the retinal veins usually are engorged. A cherry-red spot in the foveal area may be present, presumably related to retinal ischemia (Cerasoli 1971). The earliest visual field defect usually is a cecocentral or central scotoma, while later on more complex types of field defects may appear. Infrequently, the shapes of the initial scotomata may differ between the two eyes despite similar ophthalmoscopic appearances. Further examination eventually may disclose optic atrophy of the primary type, while occasional deep cupping of the nerve head may simulate glaucomatous atrophy (Fridenberg 1911). Discrete retinal hemorrhages and decreased intraocular tension have been noted in some eyes. Other ocular abnormalities found occasionally have been ptosis, extraocular muscle palsies and nystagmus.

In mild cases, and even in some with a fatal outcome, the fundi have appeared normal (Krolman and Pidde 1968). Often poor correlation has been noted between the funduscopic appearance and the severity of the visual symptoms and signs. Conversely, some patients without symptoms have had objective changes in the fundi. Rarely, chronic drinkers of small amounts of methyl alcohol who then acutely consume a large amount may have a low incidence of early visual complaints, perhaps due to an acquired tolerance to the agent (Kane et al. 1968). This may happen despite the presence of blood levels of methanol that would be toxic or fatal for previous nondrinkers. Discovery of such patients allows the institution of therapy before the establishment of significant levels of the breakdown products of methyl alcohol, thus preventing many visual complications.

Common central nervous symptoms (Bennett et al. 1953) include headache in approximately two-thirds of patients, dizziness in about a third and feelings of generalized weakness and malaise. Severely intoxicated patients may rapidly develop seizures, stupor and coma. Unconsciousness may sometimes develop extraordinarily rapidly in previously relatively asymptomatic individuals. Possible involvement of the peripheral nervous system is suggested by the histories of some patients who complain of tingling and paresthesiae in the extremities. The muscular system may be involved since severe muscle aching and tenderness in the back and legs may be prominent complaints. Neurological signs include varying degrees of mental confusion, memory loss and amnesia. Severe apprehension, maniacal behavior and delirium may occur. Reports of focal weakness are rare and no case of permanent paralysis has been reported. A syndrome of 'pseudomeningitis' has been described (Bennett et al. 1953) consisting of headache, vomiting, coma, bradycardia, hypertension, dilated nonreactive pupils, rigid neck and generalized hyperreflexia. Such patients may die in as short a time as 15 minutes from the onset of symptoms.

Gastrointestinal complaints are frequent (Bennett et al. 1953), with anorexia and severe abdominal pain being outstanding manifestations of the disorder. The pain may simulate that of an acute abdominal crisis and be accompanied by deep tenderness and abdominal wall rigidity. At times renal colic has been suggested by the descriptions of the pain. Nausea is frequent and vomiting may occur.

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Some patients may notice dyspnea, but often the respirations are slow (Bennett et al. 1953). Despite the presence of severe acidosis (see below), Kussmaul respirations are rare (Goodman and Gilman 1975). Some patients exhibit a rapid and shallow breathing pattern and severely affected patients may develop both cyanosis and rubeosis. A few patients may have hypertension. Despite the appearance of systemic shock in some individuals, hypotension is rare.

LABORATORY DATA

The most important laboratory finding in patients with methyl alcohol intoxication is that of acidosis, for the severity of visual and general symptoms relate more directly to this than to the level of methanol itself in blood or tissue (Røe 1943). The pH of the blood is low (in severe cases approaching 7.0), as is that of urine (pH may reach 5). Serum bicarbonate also is reduced markedly and in desperate cases CO_2 combining power is often less than 20 mEq/l. When this has occurred, approximately 25% of such patients have died and in some of these the CO_2 combining power fell to zero. Moderate ketonemia and acetonuria also may occur.

Sodium and potassium levels in the blood usually are normal, but vigorous bicarbonate therapy for the acidosis may result in hypokalemia if care is not taken. Serum amylase elevations related to the presence of pancreatitis have been found in many cases (Bennett et al. 1952). Hyperglycemia and elevations of lactate and pyruvate levels of blood may also occur, but likely are related to the presence of shock and acidosis (Crook and McLaughlin 1966). Albuminuria sometimes has been found in severe cases.

Some reports have indicated that CSF pressures are elevated, probably related to the presence and degree of cerebral edema, but this is not an invariable finding (Reiner 1950). CSF protein and glucose content and cell counts have been normal.

Electroencephalograms have been diffusely slow in severely poisoned patients, again correlating more with the degree of acidosis than with blood or CSF levels of methanol (Jameson and Kane 1969).

The electroretinogram also has been abnormal in the few patients in which it has been utilized, for all parameters of stimuli fail to elicit a normal beta wave (Praglin et al. 1955; Ruedemann 1961; Cooper and Kini 1962).

Electrocardiograms have on occasion disclosed diminished T-wave voltages in leads I and II with reversion to normal after therapy of the acidosis (Weisberger and MacLaughlin 1947). It is unlikely that this is a change specific for methyl alcohol poisoning. A more recent report (Hazra et al. 1974) suggests that methyl alcohol has a specific deleterious effect on the right heart, inducing an electrocardiographic pattern of right ventricular strain. This was evidenced by right atrial overload, clockwise rotation and in some cases, right axis deviation.

Rarely gas has been noted in the entire portal venous system on abdominal X-rays (after antifreeze ingestion), secondary to an acute necrotizing gastroenteritis which caused perforation of vessel walls (Fink and Boyden 1966).

METHANOL METABOLISM AND DISEASE MECHANISMS

Degradation of methanol in humans is slow and one-third of an ingested dose can remain in the body unaltered for 48 hours, with some remaining for as long as a week. Approximately 2–10% is excreted unaltered through the kidneys and most authors indicate that a similar small amount exits unchanged through the lungs (Leaf and Zatman 1952; First et al. 1970). Some investigators, however, indicate that amounts greater than 20% may leave via this portal (Keeney and Mellinkoff 1951; Cooper and Kini 1962). The vast majority of methyl alcohol in primates and man is oxidized to formaldehyde by an alcohol dehydrogenase in the liver and kidney. This same enzyme then breaks formaldehyde down to formic acid (Abeles and Lee 1960). Formic acid is six times and formaldehyde 33 times as toxic as methanol (Fink 1943). It is likely that the asymptomatic latent period noted above is terminated when these substances rise to significant levels and then exert their toxicity. About 40% of ingested methanol is excreted via the kidneys as formic acid (Keeney and Mellinkoff 1951), reaching an amount 100 times normal (Morgan and Cogan 1974). Some of the formic

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acid in the body is further oxidized to CO_2 and H_2O. Maximum values of formic acid in the urine are achieved 1–2 days after ingestion, but excretion continues for from 4–10 days (Morgan and Cogan 1974). The use of alcohol dehydrogenase to metabolize methanol is not universal in all species. A catalase system is active in most other animals and the failure to recognize this different route of metabolism caused considerable confusion in the literature until recently (Mannering et al. 1965; Kane et al. 1968).

It is generally agreed that the severe and injurious metabolic acidosis associated with methyl alcohol poisoning is from the process of metabolism and not from the alcohol itself (Røe 1969). Formic acid is thought to be the major cause of decrease in the pH and CO_2 content of the blood (Røe 1943; Clay et al. 1975), while formaldehyde is thought by many to be the agent specifically injurious to the retina. Røe (1943) believes that acidosis in general and hypoxia also play a role in the retinal injury. Consequently, substances which delay the oxidation of methyl alcohol are of assistance in the treatment of poisoning. One such agent is ethyl alcohol since it too uses the alcohol dehydrogenase system for oxidation (Røe 1943; Li and Vallee 1969). The enzyme will metabolize ethanol preferentially if the two drugs are both present in the body. Methanol metabolism is also 5–7 times less rapid than that of ethanol and proceeds independently of the concentration of methanol in the blood. Therefore, if the oxidative enzyme is tied up by ethanol, more methanol can be excreted unchanged from the body with less resultant toxicity (Røe 1950). This fact is taken advantage of in treatment, as will be noted below. Recently, 4-methylpyrazole has been found to inhibit alcohol dehydrogenase specifically and may possibly prove useful in the treatment of methanol intoxication (Blomstrand and Theorell 1970; Lester and Benson 1970; Murphy and Watkins 1972; Salaspuro et al. 1975).

When methanol enters the body it is distributed throughout the tissues in relation to their water content (Cooper and Kini 1962). The aqueous and especially the vitreous humors of the eye thus acquire the highest concentration of the alcohol (Benton and Calhoun 1952), while it is also quite elevated in gastric juices and CSF. Indeed, the concentration of methanol in gastric juice is 5–12 times greater than that in blood, even 10 days after ingestion (Cooper and Kini 1962). Absorption is rapid from the gastrointestinal tract, and the alcohol is thought to be re-excreted into the stomach for many days during the course of severe poisoning (Bennett et al. 1953).

Methanol levels in blood and urine may be measured by gas chromatographic methods (Baker et al. 1968). The breakdown product formic acid is a normal constituent of urine (Closs and Solberg 1970), but in poisoning cases it may also be found in the blood. Sometimes formaldehyde appears in the urine as well. The amounts of these two substances found in blood or urine are directly related to the amount of methanol consumed. Measurement of serum osmolality can be a guide to the identification of the amount of methanol ingested in cases of poisoning (Glasser et al. 1973; Stern 1974).

The lethal amount of ingested methanol is quite variable. One reason for this may be the lack of correct historical data from the involved alcoholics. The usual fatal dose is between 30–250 ml (First et al. 1970), but as much as 540 ml has been swallowed without irreversible toxicity. The alcohol itself infrequently causes death due to CNS depression (Potts et al. 1955), whereas the acidosis is the major reason for fatalities.

Mean cerebral blood flow and cerebral oxygen consumption have been reduced by as much as 30% in acute cases of poisoning, and these levels rise towards normal with recovery (Battey et al. 1956). It appears likely that cerebral edema and vessel wall swelling cause increased vascular resistance to blood flow, and that acidosis itself has a direct toxic effect on the brain, thus diminishing oxidative processes.

The specific retinal cell toxicity of one of the degradation products, formaldehyde, is the accepted cause of the visual symptoms and signs in primates. The retina has a greater oxygen consumption via aerobic glycolysis in proportion to its iron content than any other tissue. Formaldehyde has been found to interfere with ATP generation, to uncouple oxidative phosphorylation and possibly also to inhibit anaerobic glycolysis (Potts and Johnson 1952; Cooper and Marchesi 1959; Cooper and Kini 1962; Kini and Cooper

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1962). Thus, as a result of its toxicity to retinal glycolysis and respiration, formaldehyde has been the substance postulated to cause the degeneration of retinal cells, with resultant blindness.

PROGNOSIS

The outlook for survival is dependent mainly on the degree of severity of the metabolic acidosis and the effectiveness with which it is treated. Only in unusual cases does the narcotic effect of very high levels of methanol itself influence mortality (Goodman and Gilman 1975). Coma and seizures are not always indicative of a hopeless prognosis. Death from acidosis may be associated with a peculiar cessation of respiration, which sometimes occurs within minutes. Breathing becomes slow and shallow, after which tonic contraction of the limbs and opisthotonos may occur, followed by a great gasp and respiratory cessation with the chest locked in inspiration. The heart may continue to beat for a few minutes before failing (Røe 1955).

With regard to vision, the absence of a pupillary light reflex is generally a poor prognostic sign for life, and for eventual restoration of visual acuity (Benton and Calhoun 1952). Those who die are almost always blind or nearly so (Røe 1950). All patients with severe retinal edema usually are left with some degree of permanent visual loss. Fortunately, however, most patients do make a partial or complete recovery from their initially diminished visual acuity. Some even do so within the first hour after treatment of the acidosis. If vision does not return fully to normal within 6 days after the onset of therapy, it usually will decrease again to a low level. The longer the initial visual loss is present prior to the onset of therapy, the less likely it is that full vision will be regained, because of arterial attenuation and primary optic atrophy (Røe 1953; Krolman and Pidde 1968). The latter is usually well established in 1–2 months.

Until recently only the German literature contained a few references to persistent focal neurological defects other than optic atrophy (Riegel and Wolf 1966). These involved the development of focal cranial nerve defects and a Parkinsonian-like extrapyramidal syndrome coming on many years after the ingestion of methanol. Recently a case has been reported involving a 13-year-old girl who drank antifreeze (Guggenheim et al. 1971). Rigidity, spasticity, and hypokinesis developed 4 weeks after ingestion, with the rigidity being improved by levodopa.

PATHOLOGICAL FINDINGS

In most fatal cases, congestion, edema and some minor hemorrhages have been found in many organs (Menne 1938). Hemorrhagic pancreatic necrosis is particularly common (Burhans 1930; Bennett et al. 1952). The brain has been variably edematous with meningeal and subarachnoid petechiae being prominent (Burhans 1930; Branch and Tonning 1945). Petechiae have been especially numerous in the region of the IIIrd ventricle, aqueduct of Sylvius and beneath the floor of the IVth ventricle. Ischemic necrosis of all three layers of the cerebellar cortex also has been noted. Bilateral necrosis of the putamen involving both neurons and glia with cyst formation has been regarded by some as specific for the toxic effect of methanol on the brain (Orthner 1950; Potts et al. 1955). Experimentally, primates poisoned with methanol have been shown to develop edema and nuclear pyknosis in the putamen and caudate nuclei. One patient has been reported who had slits-haped cysts in the lateral parts of the putamena at autopsy 1 year after methanol intoxication, while another who died acutely had hemorrhages in the putamina and adjacent tissue (Erlanson et al. 1965).

Some conflict appears in the literature with regard to the ocular pathology of methanol. Some reports indicate that no retinal changes are specific for methyl alcohol (McGregor 1943), especially in patients who die early. Others would dismiss any changes found as being related to post mortem degeneration. Most authors, however, indicate that ante mortem degeneration of retinal ganglion cells is common (Fink 1943; Røe 1955; Cooper and Kini 1962). These cells may show evidence of central chromatolysis, and the degeneration extends into the inner and outer retinal granular layers. Choroidal vessels are congested and the rod and cone nuclei appear irregular. Secondary degeneration occurs in the optic

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nerves, which also may exhibit edema, hyperemia and associated gliosis.

The possibility of lateral geniculate body necrosis has been raised in one patient with a typical clinical course for methyl alcohol intoxication, but in whom laboratory substantiation of this agent could not be made (Messen 1972).

THERAPY

A tripartite approach to treatment involving the use of ethanol and bicarbonate and, in severe cases, dialysis has been developed to deal with significant instances of methyl alcohol poisoning. Rational therapy depends on frequent monitoring of methanol, CO_2, bicarbonate and pH levels in the blood.

The first parameter of treatment is the use of ethyl alcohol to saturate the alcohol dehydrogenase enzyme and thus avoid a build-up of the toxic products of metabolism (formaldehyde and formic acid) (Røe 1946; Gilger et al. 1956; Gilger et al. 1959; Gervais 1966; Li and Vallee 1969). This allows for an increase in excretion of unchanged methyl alcohol through the lungs and kidneys, also aided by giving high volumes of fluid to force diuresis (Kane et al. 1968). One schedule suggests giving 1 ml of ethanol (100 proof) per kilogram of body weight at once and 0.5 ml/kg of body weight every 2–4 hours, to maintain a blood level of 100 mg% or higher for 1–4 days (Lawrence and Haggerty 1971). Another schedule indicates that the attainment of an initial blood level of 100 mg% of ethanol requires that 1 g of this alcohol should be given for each liter of total body water (total body water is 60%, in liters, of the kilogram weight) (Rumack 1976a). The appropriate amount of ethanol should be given intravenously over a 10–15 minute period. Fifty percent ethanol solutions contain 400 mg/ml on a weight/volume basis, 420 mg/ml on a weight/weight basis and 480 mg/ml on a volume/volume basis. For maintenance, at least 7–10 g of ethanol should be given per hour (which is the excretion rate for this substance by a normal adult) but chronic alcoholics may require replacement of as much as 20–30 g/hr (Rumack 1976b). Frequent blood level determinations for ethanol are necessary to accurately monitor this form of treatment and glucose must be given in the intravenous solution to prevent hypoglycemia. Therapy may be stopped after a few days when blood methanol levels are below 20 mg/% and no acidosis is present.

Massive alkalinization is another mainstay of therapy (Chew et al. 1946; Røe 1969). 1.5 liters or more of 5% $NaHCO_3$ in 5% glucose should be given rapidly and frequently enough to correct acidosis (Røe 1969) which is monitored by serum HCO_3 and CO_2 levels and blood pH, and/or by arterial blood gases. Another authority recommends giving 3 mEq of bicarbonate/kg of body weight (Rumack 1976a). In one major epidemic, when commercially prepared solutions of bicarbonate were not available, 50 g of common baking soda for kitchen use was put into a liter of 5% dextrose in water and given intravenously, with only one pyrogenic reaction occurring with every 200 liters used (Bennett et al. 1953). Rapid alleviation of symptoms has been noted frequently as the serum bicarbonate rises toward normal.

Inasmuch as methanol is present in gastric juice and is reexcreted over a period of time into the stomach, some advocate giving syrup of ipecac to induce vomiting if the patient is seen within two hours of the ingestion (Dreisbach 1974). Gastric lavage, though not used by all because of fear of perforation of the stomach, has been advocated by many as another way of removing methanol in comatose patients, in those having seizures or when the gag reflex has been lost (First et al. 1970). Two to four liters of 3% solution of $NaHCO_3$ is used for lavage.

It is important to realize that the metabolism of methanol is slow and that treatment with bicarbonate should be carried out for 3–5 days to avoid relapses. Cases have been reported of premature cessation of treatment with resultant relapse as late as the fourth day after ingestion. Attention must also be paid to the level of serum potassium, which tends to drop with bicarbonate therapy.

The last therapeutic measure recommended is dialysis. Hemodialysis, first used in 1961 (Marc-Aurele and Schreiner 1960; Austin et al. 1961; Shinaberger 1961; Wieth and Jorgenson 1961) is usually employed when the blood methanol con-

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70 kg X 1.6 → 42 kg → 42 liters → 420 (100 ml)
420
20
8,400 cm

centration is over 50 mg% in an acidotic, clinically ill patient (Cowan 1964). Therapy with ethanol and bicarbonate is pushed while the dialysis is being set up. The procedure produces a rapid fall in serum methanol levels and results in a speedier recovery with fewer sequelae than is achieved with alkalinization and ethanol treatment alone (Keyvan-Larijarni and Tannenberg 1974). Peritoneal dialysis is also successful but is slower than hemodialysis in correcting the metabolic abnormalities (Wenzl et al. 1968).

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