



Clinical paper

Outcome after hydrogen sulphide intoxication[☆]

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ABSTRACT

Aim: Hydrogen sulphide (H₂S) intoxication in man is frequently associated with a fatal outcome. In small animal models hydrogen sulphide has demonstrated profound protection against hypoxia. No reports that focus on a potential protective effect in humans have been published.

Methods: The frequency and outcome of a large cohort of hydrogen sulphide intoxications is described.

Results: From 1980 until 2013, 35 accidents totalling 56 victims occurred of whom at least 24 (43%) survived. Of the 8 patients with documented cardiopulmonary resuscitation on the scene, 6 (75%) survived. In some of these cases with good outcome the exposure time to very high hydrogen sulphide levels before extraction and resuscitation was more than 45 min.

Conclusion: Manure related hydrogen sulphide intoxication is associated with a high mortality, although in some cases, recovery appears to be far more favourable than the initial presentation would suggest. Possibly protection from hypoxic injury due to induction of a suspended animation-like state by hydrogen sulphide may be responsible.

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Introduction

When Heracles was assigned to clean the Augean stables he managed the job by rerouting two rivers through the stables that flushed out the cow dung. This was of course a wise thing to do as it saved him considerable work, and in addition prevented him from inhaling manure gas. Today's manure storage tanks have to be cleaned more often than once in every 30 years as was the case in King Augeas' stables, but the concentration of manure gas emanating from the stored manure can be very high. One of several gases produced by decomposition of biological material is the neurotoxin hydrogen sulphide, which in small amounts is detectable by its foul smell. Hydrogen sulphide (H₂S) is a highly toxic gas that can be rapidly fatal for workers that are exposed in installations such

as manure tanks that release this compound. Many case reports and cohort studies bear witness to the lethal effects of exposure to hydrogen sulphide with often multiple fatalities.¹

However, we recently observed that a cohort of patients admitted to the ICU after out-of-hospital cardiac arrest due to an evidently very high exposure to hydrogen sulphide displayed survival that was better than expected. Furthermore, recent animal research has demonstrated that hydrogen sulphide confers strong protection against ischemia and reperfusion injury. We therefore hypothesised that in humans, apart from its toxic effect, hydrogen sulphide may also have potential protective effects that attenuates post-anoxic encephalopathy after cardiac arrest.

The aim of our study was to clarify the incidence and outcome of hydrogen sulphide intoxications with an emphasis on outcome after cardiopulmonary resuscitation and ICU admission. For that purpose we summarize the outcome of all hydrogen sulphide intoxications in the Netherlands from 1980 until 2013 and review the literature on the mechanisms of action, both toxic and protective, of hydrogen sulphide.

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Methods

After an accident with a manure store tank in which three out of four victims died the Dutch Safety Board performed a comprehensive investigation on the incidence and outcome of all consecutive suspected hydrogen sulphide poisonings in the period 1980–2013 in The Netherlands.² There was no existing overview of all manure related accidents so the Dutch Safety Board made an inventory with the use of: (1) the databank of Mrs. J. Middelkoop, Advisor Hazardous Substances of the Fire brigade Amsterdam-Amstelland and expert on the hazards of manure gasses; (2) Stigas, a knowledge institute that advises employers and employees in the agricultural sector on safety issues and healthy work environment; and (3) the Inspectorate SZW (Social Affairs and Employment) whose investigational task includes the supervision of compliance with the regulations in the area of working conditions and the prevention of major hazards involving dangerous substances. The acquired information was completed with information from the internet. For background information interviews had been performed with employees of the Dutch Federation of Agriculture and Horticulture (LTO Nederland), the branch organisation for enterprisers in agriculture (CUMELA), and the union of Dutch milk cattle breeders (NMZ).

We examined the results of this public report in detail and identified patients who had cardiopulmonary resuscitation at the scene to compare the outcome of these patients with out-of-hospital cardiac arrest in general.

For the detailed description of a patient who was admitted to our hospital we obtained oral and written informed consent according to the requirements of our Medical Ethical Committee.

A review of the literature is provided to clarify the postulated mechanism of neuroprotection by hydrogen sulphide.

Results

From 1980 through 2013 there were 35 accidents in the Netherlands with manure storage involving 56 adults with hydrogen sulphide intoxication (Table 1). Of these 56 patients 24 are known to have survived, indicating a 43% survival rate (Table 2), but 3 others most probably also survived as they were discharged alive from the ICU, which would raise the survival rate to 48%. Most fatal endings tragically happened to the ones that came to the rescue of others in jeopardy and many times there was more than one casualty. Remarkably, several fatalities involved victims who entered the toxic environment last and several survivors were those who had the longest exposure time (Table 2).

When all 8 patients during the period from 1980 through 2013 who had documented cardiopulmonary resuscitation on the scene are considered, 6 (75%) survived without neurological complications (Table 2).

There were 4 events of hydrogen sulphide intoxication within the last five years with a total of 10 adult patients of which 6 were declared dead at the scene and four who were admitted to an ICU.

In one event the single victim was declared death at the scene.

In a second event, involving both father and son, the son died while the father recovered after being admitted at the ICU. They were cleaning a barn, while at the same time manure was mixed with water in order to create a solution that would be easier to spread out on the farmland. Both were found unresponsive by a trespassing person, who alerted the emergency services. It was not clear how long they had been unconscious. Resuscitation was initiated, however, without success for the son who was declared dead on the scene.

The third event involved three non-related victims in which two victims made a good recovery and one died. One was cleaning an

empty truck tank normally carrying manure. He became unresponsive, after which his colleague entered the tank to help. When he too did not answer, a third person climbed into the tank, while a fourth called the emergency services. After fifteen minutes, all three were extracted. Resuscitation resulted in return of spontaneous circulation (ROSC) in all three, though their Glasgow Coma Score remained 3. They were admitted to the ICU. Two regained consciousness and could be extubated the next day. The third person, who had entered the tank last, never woke up and eventually died.

The fourth event involved four non-related victims in whom one made a good recovery and while the three others died. An employee of a professional cleaning company became unresponsive while cleaning the bottom of a manure tank, although he wore an oxygen mask. His colleague climbed down the tank for assistance and collapsed as well. A wage labourer as well as the farmer's son noticed something was wrong and both entered the tank without oxygen in order to try and rescue the other two. The farmer had discovered the disaster at the manure tank and alerted the emergency services. Pending the arrival of the paramedics the farmer, who knew that his son was inside, unsuccessfully attempted to open the tank with a forklift truck. After a 45-min rescue operation the four victims were extracted. The two professional cleaners and the farmer's son were pronounced dead at the scene after fruitless resuscitation attempts were made. The 23-year old wage labourer (patient 55, Table 1) had no cardiac action after he was extracted, but after some chest compressions and ventilation, he quickly restored to normal sinus rhythm with ROSC. He showed some movement of his limbs, but had no sign of spontaneous breathing and therefore was intubated at the scene. Thirty minutes after the start of resuscitation, this patient arrived at our University Hospital where he was admitted at the ICU. The patient was sedated with propofol and treated with controlled hypothermia with a target temperature of 33 °C for 24 h after which he was passively warmed to 36 °C in approximately 3 h after which sedation was stopped. After 12 h without sedation his neurologic examination revealed no signs of improvement. No additional examinations like an electric encephalogram (EEG) or somatosensory evoked potential (SSEP) were ordered. Ninety-six hours after his extraction from the tank, the first progression in his consciousness was seen with a motor score that fluctuated between M2 and M4. During the following week his neurological state steadily improved to E4M6V1. At that time, nine days after the accident, he was discharged to the ward where further neurologic evaluation took place. He showed involuntary movements and although he had a clear consciousness and nodded correctly if he was asked a simple question, he appeared to be mute. Furthermore, he displayed a slight left-sided hemiparesis.

Twenty-three days after the event he was transferred from the hospital to a rehabilitation centre. His GCS at that time remained E4M6V1. After 4 months, he came in walking without support to visit our ICU and spoke, although still bradyphrenic and with a dysarthric speech and restricted vocabulary. His hemiparesis had disappeared. Furthermore, his mother informed us that he could already drive the tractor again.

In summary, four out of five (80%) patients who were admitted to an ICU in the last 5 years after hydrogen sulphide intoxication made a good recovery.

Discussion

Hydrogen sulphide intoxication in manure barns is evidently a very severe event since it was associated with more than 50% mortality. It underscores the danger of working with large quantities of manure in restricted spaces. However, the survival rate of the 8 patients with documented CPR (75%) after hydrogen sulphide intoxication is far better compared to survival rates of OHCA

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