

Homicidal Paraquat Poisoning in Exhumed Case

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Received: April 19, 2015

Revised: April 28, 2015

Accepted: May 8, 2015

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Paraquat is a nonselective herbicide, but its lethal and toxic effects are well known. Although its chemical additives have an unpleasant taste, this can be shrouded in spicy foods or drinks with strong tastes, and some symptoms and signs of paraquat poisoning can be mistaken as natural disease. For this reason, it is not easy to consider the possibility of homicidal paraquat poisoning for a clinician or even for a forensic pathologist. We present a case of homicidal poisoning by paraquat with significant forensic findings from postmortem examination and with a review of relevant literature.

Key Words: Paraquat; Homicide; Poisoning; Autopsy; Forensic pathology

Introduction

Paraquat is a nonselective herbicide that has been widely used all over the world. However, because of its severe toxicity and lethal effects, its use is no longer allowed in several countries [1,2]. According to a 2008 report of toxic exposures in Korea, the most common cause of intoxication case was pesticide (30.7%), which included fungicides, herbicides, insecticides, miscellaneous pesticides, repellents, rodenticides, and others [3]. Among all these various cases, the most commonly used agent was paraquat (31.0%) [3]. Therefore, the Rural Development Administration, a

Korean governmental organization, cancelled the registration of paraquat as an agrochemical, and prohibited by law and made legally punishable its production, storage, sales, and use in 2012.

Paraquat is originally an odorless chemical, but a stanching agent or emetic is added into it in order to avoid accidental poisoning [1]. Therefore, it is generally considered difficult to kill someone through oral administration because of its disgusting taste. In our nation, only two homicidal cases of paraquat poisoning by injection, and not by an oral route, have been reported [4]. If a small amount of paraquat is added to spicy foods or a drink with a strong taste, its sickening smell can be veiled. In this case, intentional oral ad-

ministration is possible. Recently, the authors experienced a rare case of homicidal paraquat poisoning assumed to have occurred via oral administration. To the best of our knowledge, this would be the first reported case of homicidal paraquat poisoning by oral administration nationwide. We present this case with a review of the literature and significant forensic findings in regards to postmortem examination.

Case Report

1. Case history

The deceased (victim A) was an 81-year-old woman. She had complained of sore throat and difficulty swallowing for about 2 weeks. For a few days, victim A's condition was observed by her family at home, but then she abruptly developed a fever. On the next day (the fifth day of observation), victim A was transferred to a hospital because her fever did not improve and her condition was worsening despite medication. Two days later, victim A experienced severe dyspnea due to pneumonia in both lungs. She was transferred to another hospital. Three days later, victim A died despite intensive treatments. Victim A's death certificate stated that the cause of death was pneumonia and the manner of death was natural. Victim A had a past history of diabetes mellitus and hypertension, well controlled by medication.

Subsequently, victim B (victim A's son) started chronically suffering from interstitial lung disease (diagnosed as bronchiolitis obliterans organizing pneumonia) of unknown cause. Although victim B was repeatedly admitted to a hospital, he did not recover and eventually died. Because victim B's wife (victim A's daughter-in-law) was a beneficiary of the life insurance policy upon victim B's deaths, the deceased's family alleged that victim B's wife (victim A's daughter-in-law) might be responsible for both deaths. A family member remembered a story victim A told 5 months ago; she had once taken an unknown drink, labeled as a health drink, from a fridge and sipped it. Victim A threw up immediately because of its strange

chemical taste. Victim A saw that the vomit was colored blue or green and remembered that the drink was already uncapped. Considering the request from the deceased's family, the police investigated this case. Due to the consecutive questionable situations around both victim A and B's deaths, they decided to reexamine victim A's cause of death. They did not reexamine victim B's death because his body was already cremated. Since it has been about 2 years after victim A's death, her body was exhumed and our institute consulted on the postmortem examination.

2. Autopsy findings

On external examination, the body was severely decomposed, but there were no open wounds and the skin was intact on most parts of the body. On internal examination, internal organs were decomposed and the brain showed liquefactive necrosis. Coronary arteries revealed mild to moderate atherosclerosis. It was difficult to determine whether pneumonia had been in both lungs or not due to postmortem putrefaction. There were some punctuate hemorrhage on the gastric mucosae, and there were no gastric contents. In other internal organs, there were no mass-like lesions. No fracture was identified in the body.

Most of the blood was not available because of severe decomposition, but it was possible to collect a small amount of blood samples from the heart. The body fluid in the pleural cavity was also collected. Given that the deceased was admitted to a hospital for about five days and postmortem putrefaction was advanced, extensive sampling from several internal organs was done for toxicological tests. Tissues from the stomach, liver, kidney, spleen, lung, and bone marrow were taken. Toxicological analysis was performed by using ultra phase liquid chromatography–tandem mass spectrometry. Paraquat was detected on tissues of the stomach, liver, kidney, spleen, lung, and bone marrow, but not in the blood or body fluid. The concentration from each tissue was 1.5 ng/g (stomach), 1.3 ng/g (liver), 5.5 ng/g (kidney), 4.2 ng/g (spleen), 0.8 ng/g (lung), and 2.3 ng/g (bone marrow). The cause of

death was determined to be paraquat poisoning.

Discussion

Paraquat (1,1'-dimethyl 4,4'-bipyridinium dichloride) is a herbicide that was first synthesized in 1882. Its commercial introduction as a nonselective herbicide was launched in 1962 [1]. This chemical was considered an agricultural revolution because it can be sprayed, completely denatures on contact with the earth, and does not harm the seeds or saplings after use. Because of these qualities, its use lead to economic gains, such as increased crops at harvest [1]. Paraquat is brown-colored, highly water-soluble, and odorless, so a stanching agent or an emetic is added in order to prevent unintentional use [1].

Once paraquat is administered and absorbed in the body, it is poorly absorbed (an approximate 10%–13% absorption rate [2,5]). It rapidly distributes into other tissues, with maximum tissue levels attained about 6 hours after ingestion [5]. The absorbed paraquat is concentrated inside cells. It is actively taken up by the spermidine/putrescine and other cell membrane transporters in the lung, kidney, liver, and muscle tissues, where redox cycling progresses repetitive enzyme-mediated cycling between paraquat and paraquat radicals [5,6]. The by-product of this process is a superoxide radical, resulting in cellular damage or inducing other reactive oxygen species [6]. This process consumes

NADPH, which is one of the anti-oxidant defenses. This leads to cell damage and induces a secondary inflammatory response. Paraquat is largely eliminated unchanged in urine because it does not undergo significant phase I or phase II biotransformation. However, a small degree of metabolism probably occurs in the gut as a result of microbial metabolism. The rate of excretion of paraquat is more than 90% in 72 hours [5,6].

The formulation of the concentration of paraquat and its dose is important in that swallowing more than 30 mL (a mouthful or two) of 20%–24% paraquat concentrate is usually lethal, and as little as 10-mL can cause significant illness [7]. If there is a past history of kidney disease and the person is aged >50 years, worse outcomes can occur [7,8]. Typical symptoms and signs of paraquat poisoning are a painful mouth and pain with swallowing accompanied by inflammation and even ulceration of the oral mucosa or esophagus [1]. The lungs are highly susceptible, and renal and hepatic failure might occur in 2–4 days [1]. Over a period of hours to days, it can lead to multi-organ failure [9].

The postmortem findings of paraquat poisoning are dependent on its toxic process. The findings include the following [1]: ulceration around the lips and mouth, reddened and desquamated mucosa in the oral cavity and on the esophagus, pseudomembranes in the pharynx, patchy hemorrhages in the stomach

Table 1. Paraquat concentrations in postmortem tissues (ng/g of tissue), urine, and cardiac blood: comparison of our case with other cases

Tissue/Blood	Concentration (ng/g or ng/mL)					
	Case 1	Case 2	Case 3	Case 4	Case 5	Our case
Lung	11,856	660	5,095	2,231	500	0.8
Liver	4,355	340	973	879	100	1.3
Spleen	Not done	Not done	Not done	Not done	Not done	5.5
Kidney	5,662	575	1,044	1,145	998	4.2
Heart	23	1	3	7	Not detected	Not done
Duodenal wall	3,100	260	2,320	168	2,830	Not done
Gastric wall	1,234	190	200	94	160	1.5
Diaphragm	305	16	130	131	10	Not done
Urine	13,539	78	592	177	500	Not done
Cardiac blood	19,500	Not detected	290	90	Not detected	Not detected
Bone	Not done	Not done	Not done	Not done	Not done	2.3

Adopted from Dinis-Oliveira RJ, et al. PLoS One 2009;4:e7149, according to the Creative Commons License of PLoS [10].

mucosa, pallor changes in liver and kidney, acute tubular necrosis and renal cortical necrosis, centrilobular hepatic necrosis, cholestasis with giant mitochondria and paracrystalline inclusion bodies, edematous disaggregation of the sarcoplasm, and sporadic fragmentation of the myofibrils. The most distinct findings are observed in the lungs. Each lung is typically approximately 1,000 g or more in weight. Alveolar epithelial cells are destroyed, followed by inflammatory cell infiltration, hemorrhages, and fibroblast proliferation, which leads to fibrosis and impaired gas exchange.

Several homicidal cases have been reported [1]. In one case, the deceased was killed by his wife who had a friend with knowledge of agrochemicals. She administered paraquat to him repeatedly in small doses, and he became ill. Thirteen days later, he died with signs and symptoms of paraquat poisoning. A postmortem examination proved his cause of death.

In the second case, four people had a party and paraquat was slipped into one of their beers for an unknown reason. The man drinking the beer suffered from paraquat poisoning symptoms and died.

In the third case, a wife killed her husband by mixing paraquat twice in a pie. He complained of a sore throat and was prescribed medicine for treatment. She added paraquat into his medicine, and he died after 24 days of illness. His cause of death was cardiac arrest in combination with renal failure and bilateral pneumonia. When eight months had passed since his death, paraquat poisoning was proven by detection from the deceased's preserved tissue in the mortuary.

In the fourth case, a man who had been married five times killed his fourth and fifth wives. After they asked for a divorce, they became ill and died after several days. A few months after these deaths, his 79-year-old mother also died. All three deceased showed typical symptoms of paraquat poisoning, and the autopsy findings showed natural disease of the lungs. Toxicological analysis was performed on the fifth wife and the mother, and paraquat was detected in their tissue. The man was a mechanic on a large agricultur-

al ranch.

In the fifth case, the deceased was a registered herbicide user, and he had a marital affair with a wife who stood to gain substantial insurance compensation upon her husband's death. He died after 21 days of illness and after denying suicidal ingestion. However, no toxicological test was performed, and this case was considered an equivocal suicide or homicide.

The authors who reported the fourth and fifth cases suggested that in cases with symptoms of viral pneumonia, the possibility of paraquat poisoning should be considered, and in all doubtful cases, a full toxicological analysis should be performed and the tissues should be particularly analyzed for paraquat [1].

In our case, approximately two years had passed between the deceased's death and the investigation and the postmortem examination. It was therefore very difficult to get the exact information about the scene of her death. However, based on the statement of the deceased's family that she sipped a health drink with an uncapped lid a few months before her death, we could assume that a small amount of paraquat might have been administered repeatedly, mixed with spicy foods or with a strong-tasting drink. The deceased showed symptoms of a sore throat and swallowing difficulty, which are typical symptoms of paraquat poisoning. Because she displayed the typical clinical course of pneumonia during her illness, a past history of poisoning was not revealed to her clinicians. Moreover, pneumonia is one of most common causes of death in old age and it would be nearly impossible to consider paraquat poisoning at the time of her illness and death. The postmortem examination was not performed because this case was considered as natural death by the clinician. If postmortem examination was never performed, this case might have gone unnoticed. Consecutive questionable situations around her death finally led to an investigation. However, even in cases of doubtful natural death, postmortem examination should be carried out along with toxicological examination.

Because the exhumed body was already decom-

posed, it was difficult to evaluate oral or esophageal mucosa. Most internal organs showed postmortem putrefaction, but petechial hemorrhage on the gastric mucosa, consistent with paraquat poisoning, was identified. Extensive tissue sampling with a little remaining blood and body fluid was carried out for toxicological analysis. The result revealed that paraquat was not detected in the blood and body fluid, but in the tissues of the stomach, liver, kidney, spleen, lung, and bone marrow. The concentrations in our case were much lower than those of other reported cases (Table 1) [10]. We assumed that because the body was decomposed, lower levels of paraquat were observed upon testing, and also that treatment occurred for some time before death. In our case and in other cases [10], paraquat was not detected in the blood, but could be identified in tissues of the lung, kidney, liver, gastric and duodenal walls. In those who are poisoned by paraquat and survive for several days, extensive tissue sampling for toxicological analysis would be essential.

Determination of homicidal poisoning or intoxication can be a challenge to forensic pathologists, because it is difficult to ascertain the exact information of the situation around death. Even though paraquat is not allowed for distribution or use anymore, paraquat is still used and in stock in rural areas. If the subject complains of sore throat, swallowing difficulty, and gastrointestinal symptoms, or if the clinical course of pneumonia is unusual or rapidly aggravated with multi-organ failure with symptoms as described above, the possibility of paraquat poisoning should be considered. Where these symptoms end in death, post-

mortem examination with full toxicological analysis should be done, with extensive tissue sampling as well as blood testing.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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