SMJ Singapore Medical Journal

Secondary exposure to organophosphate in the emergency department: analysis of an incident

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Singapore Med J 2021, 1–15
https://doi.org/10.11622/smedj.2021220
Published ahead of print: 26 November 2021

INTRODUCTION

Organophosphate (OP) insecticide poisoning is a rare occurrence in non-agricultural countries like Singapore. The risks of secondary exposure to healthcare workers (HCWs) attending to the patient with OP poisoning have been described in several case series.[1–4] However, most reports did not include serum cholinesterase measurements to deduce if patients were indeed poisoned.

We describe an incident of secondary exposure of HCWs to a patient who was admitted to the Emergency Department (ED) for maldison poisoning from an insecticide containing 500 g/L malathion dissolved in a 487 g/L hydrocarbon solvent. We also report the measurements of the cholinesterase levels of both the index patient and affected HCWs.

METHOD

A post-incident investigation was carried out as part of mandatory risk management reporting. Staff involved were identified from the roster assignments on the day of the incident. Consent was taken before enrolment for the survey. All staff present during the incident reported the extent of contact with the index case, the duration of exposure, timing and nature of their symptoms. Retrospective review of medical records of the index patient and affected HCWs who presented to the ED was done to elucidate their treatment, disposition and cholinesterase levels.

This study was approved by Institutional Review Board at SingHealth, Singapore (CIRB Reference no. 2020/2165).

RESULTS

Index patient

A middle-aged man presented to the ED for OP ingestion. He was found at home foaming at the mouth lying next to a 100 ml bottle of insecticide along with alcohol. Paramedics found him drowsy and diaphoretic, and he was conveyed via ambulance to the nearest hospital.

The patient was wheeled directly into the ED resuscitation room which was located within an enclosed, air-conditioned indoor area. The paramedics had brought along the bottle of the ingested agent (Horti-on Insecticide – 500 g/L maldison, an anti-cholinesterase compound; solvent 487 g/L liquid hydrocarbon). The patient had a heart rate of 152 bpm, blood pressure of 149/100 mmHg, respiratory rate of 20 and an oxygen saturation of 100% on non-rebreather mask. He was unconscious and diaphoretic with pinpoint pupils, and his clothing was soaked in vomitus. The decision was made for emergency intubation to promptly secure his airway. Thereafter, the Hazardous Material (HAZMAT) decontamination unit (HDU) located outdoors adjacent to the resuscitation zone was activated. The patient's clothing were removed, bagged, sealed and discarded in biohazard bins and the patient's skin was washed thoroughly using liquid soap and running water following the hospital decontamination protocol.[5] A chemical agent detector was used to ensure that the patient was washed free of the toxic agent before further resuscitation efforts were continued. Meanwhile, the toxicologist-on-call was consulted, and treatment with pralidoxime (2 doses of 1g over 30 minutes) and atropine (2.4 mg then 4.8 mg infusion) was initiated for the patient. Propofol and fentanyl infusion were used for post intubation sedation and analgesia and the patient was admitted to the intensive care unit for further management. Serum cholinesterase levels taken on the day of ingestion was <1000 U/ml and remained low until day 5 on which it rose to 1169 U/ml. Red blood cell (RBC) cholinesterase was 3221 U/ml (Fig. 1). He was extubated successfully on day 4 after further treatment with pralidoxime and atropine, moved to high dependency for the next

3 days and recovered uneventfully in the general ward for another day before discharge after a full recovery.

Secondary exposure to healthcare workers

Three paramedics conveyed the index patient to the hospital. No primary decontamination was conducted at scene. Dressed in short-sleeved uniforms, surgical gloves and masks, the paramedics attended to the patient for approximately 30 minutes, suctioned the patient's oral secretions and carried the patient whose clothing was drenched in vomitus onto the stretcher. They reported an overwhelming odour of the insecticide during transport for which they had to open the windows of the vehicle for better ventilation. One paramedic developed nausea during conveyance and started vomiting soon after arrival to the hospital. The second paramedic who was also at the back of the ambulance developed giddiness and vomiting about 15 minutes after arrival to ED. The ambulance driver reported headache and giddiness thereafter. All the paramedics underwent decontamination in the HDU.

The resuscitation team managing the index case consisted of 3 doctors (a senior Emergency specialist, a senior resident, a clinical associate) and 4 nurses. All of them were dressed in short-sleeved scrubs, surgical masks and gloves when they received and intubated the patient within the enclosed resuscitation room. Only after the patient was decontaminated did they don on disposable isolation gowns. The duration of exposure was approximately 15 minutes from arrival to decontamination of the casualty. The 4 resuscitation nurses, who reported ill, had more prolonged exposure to the patient compared to the doctors. An additional nursing staff was called upon to help care for the patient in the resuscitation room post-decontamination. He had donned on a disposable long-sleeved gown over his scrubs, gloves and N95 mask while attending to the patient and reported light-headedness afterwards.

The HDU team consisted of 3 nurses who were in full HAZMAT suits (Paul Boyle Technologies CLD500 fully encapsulated overall with powered air purifying respirator) during the decontamination process. They too sought medical treatment shortly after attending to the index patient and paramedics despite being adequately protected throughout patient contact. Table I summarizes the details of the patient encounter, extent of exposure and symptoms of the HCWs who sought medical treatment at the ED during the incident.

Altogether, 14 healthcare workers developed symptoms soon after contact with the index patient with 12 seeking medical attention in the ED. The 2 staff who declined to be assessed had spontaneous resolution of symptoms. Staff attrition rate was 14.7% (9/61) among ED doctors and nurses on that particular afternoon shift. Reported symptoms (Table I) included sore throat (1), watery eyes (2), headache (2), giddiness (4), light-headedness (5), nausea (1) and vomiting (2). No HCWs displayed typical OP poisoning toxidrome such as excessive secretions, narrowed pupils or diarrhoea. ED staff who had no direct contact with patient did not report any symptoms. Severity and time of onset of symptoms appear to correlate with duration and extent of exposure to the patient. Risk assessment of the exposed HCWs was carried out by the attending physician in consult with the toxicologist-on-call.

Eight HCWs (3 paramedics and 5 nurses) attending to the index patient prior to decontamination had potential dermal and inhalational exposure were deemed moderate risk. The 3 paramedics underwent decontamination at the HDU while all affected nurses were asked to shower and change out of their uniforms. A single dose of Duodote auto-injector (2.1 mg atropine/600 mg pralidoxime chloride) was administered to one of the paramedics who experienced severe giddiness and vomiting in the ED based on suspicion of secondary OP poisoning. The other 7 HCWs were treated symptomatically. The moderate risk group had serum cholinesterase and RBC acetylcholinesterase levels measured and were admitted to the

ED observational unit. None had significant reduction in measured enzyme levels and all were discharged well after 8 hours of observation.

Four nurses (3 HDU and 1 resuscitation) who attended to the patient with appropriate personal protective equipment (PPE) reported non-specific symptoms. They were assessed clinically and deemed low risk. Their vital signs and physical examinations were normal hence blood investigations were not required. They were discharged with outpatient medical leave. All symptomatic HCWs, including the 2 doctors who did not seek medical attention, reported complete resolution of symptoms on follow-up.

DISCUSSION

OP agents comprise a heterogeneous family of over 50,000 compounds. They can be found in pesticides (e.g. malathion), medications (e.g. neostigmine), commercial chemicals (e.g. lubricants) and nerve agents meant for chemical warfare (e.g. sarin).[6] In developing nations, widespread OP pesticide use for agriculture has reportedly led to many cases of intentional and non-intentional poisoning through dermal, inhalational, oral and rarely, intravenous routes.[6] The World Health Organization (WHO) gives an estimate of three million cases of pesticide poisoning annually worldwide, resulting in an excess of 250,000 deaths per annum.[7]

OP compounds bind and irreversibly inhibit several enzymes including RBC/synaptic acetylcholinesterase and serum cholinesterase. Acetylcholinesterase inhibition leads to acetylcholine accumulation at nerve synapses and neuromuscular junctions, receptor overstimulation and paralysis of cholinergic synaptic transmission. Signs of OP poisoning are secondary to overstimulation of muscarinic, nicotinic, and central nervous system receptors. Muscarinic effects include miosis, bradycardia, and overstimulation of bronchial glands. Nicotinic effects include muscle fasciculations and flaccid paralysis. Onset and severity of symptoms depends on the specific compound, amount, route of exposure, and rate of metabolic

degradation. Without medical intervention, severe poisoning leads to lethal respiratory failure.[8,9] Treatment for OP nerve agent uses three types of therapies: antimuscarinic, oxime, and anticonvulsant. The antimuscarinic drug atropine is a key component of treatment.[10] Some OP pesticides, such as the one ingested by our index patient, contain a hydrocarbon solvents which are volatile and cause gastrointestinal symptoms as well as giddiness and headache when inhaled.[11]

The actual risk of secondary poisoning in HCWs through nosocomial exposure is uncertain as it is not ethical to conduct randomised controlled trials on human subjects to study this risk. Evidence from several reported incidents are not robust enough to make firm conclusions.[1–4] One reported incident of nosocomial exposure to a patient who ingested a veterinary insecticide concentrate comprising of naphthalene, xylene and phosmet resulted in severe symptoms in 3 HCWs. One required intubation and ICU admission. In this incident, decontamination was not performed on the index case, the staff were not wearing adequate PPE and cholinesterase levels were not assayed.[2] In another report, 2 individuals developed symptoms after performing mouth-to-mouth resuscitation on an OP-poisoned friend in the pre-hospital setting. The index patient died in the ED despite resuscitative efforts. Both first-aiders were treated with atropine and pralidoxime without having their cholinesterase levels assayed.[4] Only one report included cholinesterase levels of 14 symptomatic HCWs after nosocomial exposure to a patient with lethal malathion overdose without adequate PPE. The blood investigations showed no systemic OP poisoning in the HCWs.[1] The lack of reporting of nosocomial poisoning in countries where HCWs often tend to patients with suicidal ingestion of OP pesticide without adequate PPE suggests that the risk may be low.[12]

Acute dermal and inhalational exposure to pesticides may carry minimal risk for OP poisoning given that OP compounds, in order to be effective as pesticides, have extremely low volatility. However, most OP pesticide formulation also contain a hydrocarbon solvent which

is highly volatile and more likely to cause symptoms upon inhalation.[12] Nevertheless, safeguards against both acute and chronic occupational exposure is still widely recommended. In the agricultural setting, the World Health Organisation guidelines recommend various safety measures when dealing with pesticides including the use of long-sleeved shirts, long trousers, boots, socks and chemical-resistant gloves.[13] In Singapore, legislation mandates 6-monthly medical examinations to monitor clinical symptoms and RBC acetylcholinesterase levels for factory workers handling organophosphates. Plasma ChE estimations are recommended only in acute OP overexposure.[14]

HAZMAT incidents are rare and this incident provides an opportunistic insight into the potential consequences of secondary exposures during a crisis. Fortunately, this case involved an OP with limited transmissibility. It provides further evidence that the actual risk of OP pesticide poisoning through dermal and inhalational routes during nosocomial exposure is low. Reported symptoms and cholinesterase levels did not indicate systemic OP poisoning. Symptoms developed may instead be due to hydrocarbon inhalation, mild localized OP poisoning or side-effects of donning HAZMAT suits. The environment within the HAZMAT suit contains air filtered by the canister on the air purifying respirator which removes chemical contaminants from the ambient environment and pumps it into the suit. This is an active process creating positive pressure within the suit with a one-way flow. The canisters also have a lifespan of several hours before breakthrough and as such there is low likelihood for chemicals to enter or build up within the suit and recirculate. However, wearers may develop non-specific symptoms from heat- or confinement-related effects.

Furthermore, the impact of psychological stress reactions during HAZMAT incidents should not be underestimated and needs to be dealt with expeditiously to avoid closure of EDs during disasters.[3] During this incident, ED staff attrition rate was 14.7% (Table II). Studies have shown quantifiable impact of perceived risk with symptomatology.[15,16]

HCW safety and healthcare facility integrity are critical issues that need to be addressed to allow continuity of care during a HAZMAT incident.[17] ED preparedness and staff training is essential. Taking various factors into account, it is essential to minimize nosocomial exposure with prompt decontamination and standard precautions. In managing a case of OP poisoning, for instance, appropriate skin and respiratory protective equipment should be worn. Any inadvertent skin contamination should be washed immediately. The index patient should be attended to in a well-ventilated area when possible.[12] These steps not only mitigate the risk of actual secondary poisoning but may also contribute to psychological well-being of HCWs involved.

Exposure to nerve agents are particularly concerning as these, having been developed for chemical warfare, are more potent, volatile and hence more easily transmissible.[10] EDs should adhere to universal guidelines for HAZMAT incidents which include decontamination protocols, adequate PPE training and supplies, and maintenance of adequate antidotes supply. Specifically, frontline staff including paramedics should be educated on the routes and risks of secondary exposure to various HAZMAT agents, the appropriate PPE and steps to minimise their own risks of exposure. Decontamination of the index patient should also be prioritised, not only for the patient's benefit but also in order to safeguard both the physical and psychological well-being of HCWs and prevent unnecessary staff attrition during incidents.[2] HAZMAT decontamination stations should also be an integral part of the infrastructure of all EDs.[18] Institutional protocols should aim at protecting staff from any toxic encounter. However, when the agent involved is known to have minimal toxicity, there is a potential to reduce protective gears at the discretion of a knowledgeable team leader preferably after consultation with a toxicologist. The rationale for the deviation from protocol should be informed to the staff and documented in the clinical notes accordingly.

This incident highlights the importance of risk stratifying secondary exposure victims. In the event of a mass chemical incident, appropriate risk assessment and right-siting of patient will have significant downstream effects in maintaining balance between safe discharge and reducing admissions in order not to overwhelm the healthcare system. Patients deemed as low risk thorough clinical history taking and physical examination can be discharged. Patients deemed moderate risk based on clinical symptoms and likely dermal and inhalational exposure can be managed in the ED observation ward for short-term care. High risk patients presenting with cholinergic toxidrome after confirmed contact with the index case without proper PPE will require inpatient admission and administration of antidotes.

The limitation of this study includes its retrospective nature and the small number of healthcare workers involved. Much of the timeline elicited is based on first hand recall of the incident. This account also only provides insight into the effects of a single OP agent (Malathion) and cannot be generalised. Furthermore, the contribution of psychological stress reaction was not evaluated in this incident.

In conclusion, secondary exposure to certain organophosphate containing pesticide like malathion, through dermal and inhalational means may not be as dangerous as suggested in some literature. None of the exposed staff developed symptoms or cholinesterase levels suggestive of acute poisoning. Although mild OP poisoning may be a possibility, the symptoms experienced are more likely due to inhalation of the volatile hydrocarbon vehicle, the effects of donning on HAZMAT-suit or psychological stress reactions from being exposed to a perceived toxic agent. However, it is still prudent to exercise universal precautions when dealing with any chemical incident and perform early decontamination to reduce staff attrition rate resulting from other factors.

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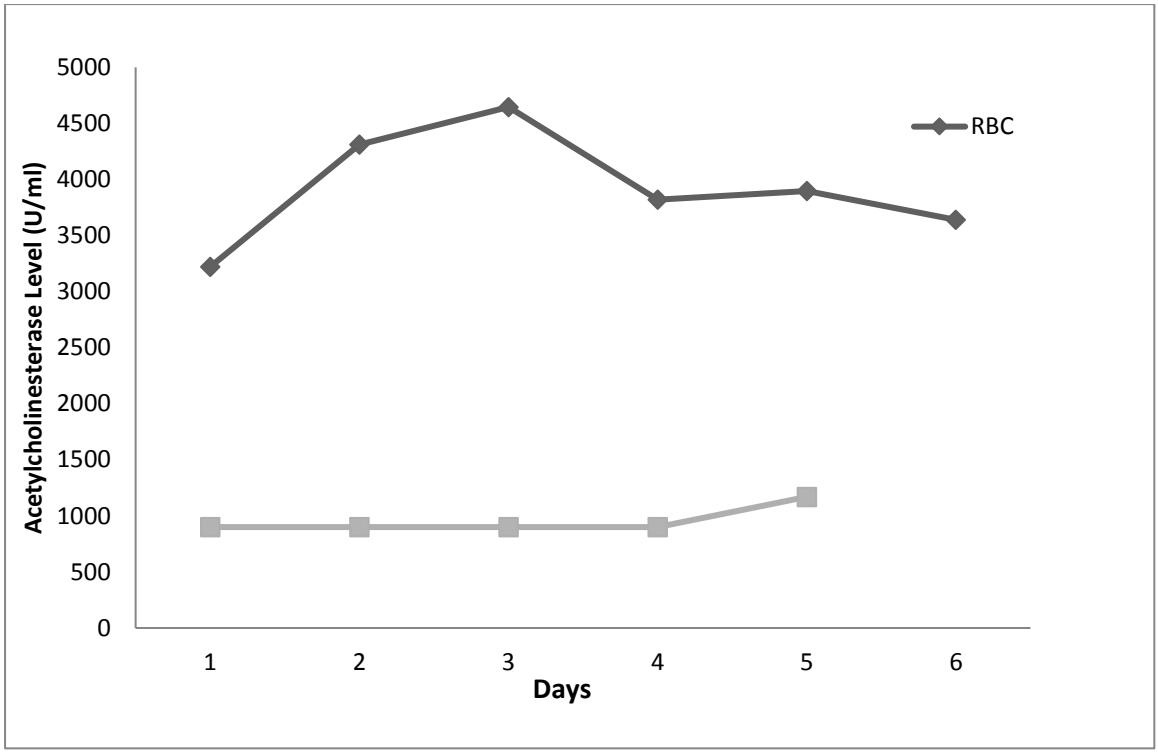

Fig. 1 Trend of red blood cell and serum acetylcholinesterase level of index patient

Table I: Characteristics of healthcare workers who presented to the ED with symptoms after secondary exposure to organophosphate containing pesticide (Maldison).

No	Age, Sex	Designation, Work area	Degree of contact with index patient	PPE	Symptoms @ Time of onset	Management	SC (U/ml) [4.7-12K]	RC (U/ml) [7.7-14.6K]
1	26,M	Paramedic, prehospital	Pre- decontamination. Attended to patient at scene and within cabin of ambulance	Face mask, gloves	Vomiting, giddiness @ 10min	DuoDote EDTU	8164	14063
2	23,F	Paramedic, prehospital	Pre- decontamination. Attended to patient at scene	Face mask, gloves	light headedness, sore throat@ 20min	EDTU	14257	11779
3	36,M	Paramedic, prehospital	Pre- decontamination. Attended to patient at scene and within cabin of ambulance	Face mask, gloves	Vomitting, giddiness @ 5 min	Maxalon EDTU	8187	16756
4	33, F	Assistant Nurse Clinician, Overall In-charge	Pre- decontamination. Assisted in patient care prior and after decontamination	Face mask, gloves before Intubation N95, Yellow gown, gloves after intubation	Nausea, giddiness @ 82min	Maxalon. EDTU.	8995	12074
5	29, M	Staff nurse, Resus/Ambulance triage	Pre- decontamination. Assisted in patient care prior to decontamination HDS team that did the decontamination	Face mask, gloves before Intubation HAZMAT suit for decontamination	Headache, Giddiness @ 3hours	Maxalon Anarex EDTU	8444	12335
6	32, M	Senior staff nurse, Resus	Pre- decontamination. Assisted in patient care prior to decontamination	Face mask, gloves before Intubation N95, Yellow gown, gloves after intubation	Watery eyes, chest pain @ 30min	ECG Maxolon EDTU	11457	12181
7	24, M	Staff Nurse, Resus	Post-decontamination. Assisted in patient care after decontamination was done.	N95, Yellow gown, gloves after intubation	Lightheadedness @ 3hours	Discharged	NA	NA

8	21, F	Staff Nurse, Resus	Pre- decontamination. Airway nurse during intubation	Face mask, gloves before Intubation N95, Yellow gown, gloves after intubation	light headedness, nausea NO vomit @ 5min	EDTU	9652	10056
9	22, F	Staff Nurse, Resus	Pre- decontamination. Assisted in patient care prior to decontamination, circulating nurse in resus	face mask, gloves, yellow gown	Palpitations @ 5min	EDTU	6977	11956
10	26 ,F	Staff Nurse, HDU	Performed decontamination	HAZMAT suit	mild giddiness, frontal headache @ 5min	Discharged	NA	NA
11	23, F	Staff Nurse, HDU	Performed decontamination	HAZMAT suit	light headedness @ 5min	Discharged	NA	NA
12	28, M	Staff Nurse, HDU	Performed decontamination	HAZMAT suit	headache @ 5min	Discharged	NA	NA

ECG – Electrocardiogram
EDTU – Emergency Diagnostic and Treatment Unit
BVM – Bag, valve mask ventilation
HDU – HAZMAT decontamination unit
PPE – Personal protective equipment
SC - Serum cholinesterase (normal range: 4700-12000 U/ml)
RC - RBC cholinesterase level (normal range 770-14600 U/ml)

Table II: Overview of exposure of department personnel during affected shift

Personnel	No.	Location	Extent of Exposure	No. Symptomatic	No. Reported ill
Paramedics	3	Prehospital	Pre-decontamination Direct contact	3	3
Doctors	**15**				
Resus doctors	3	Resuscitation	Pre-decontamination	2 (watery eyes, nausea)	0
Non-resus doctors	12	Other zones	No exposure to index patient. 5 managed secondary cases.	0	0
Nurses	**43**				
Triage nurses	2	Ambulance Triage	Pre-decontamination Direct contact	1	1
Resus Nurses	4	Resuscitation	3 Pre-decontamination 1 Post-decontamination	4	4
ANCs (Overall I/Cs)	4 (including 2 recall)	All zones including resuscitation	1 Pre-decontamination 3 No exposure to index patient.	1	1
HDU team	3	HDU	During decontamination	3	3
Non-resus nurses	30	Other zones	No exposure to index patient. 4 managed secondary cases	0	0
TOTAL HCW	**61**	**Prehospital and ED**		**14**	**12**
TOTAL ED Staff	**58**	**ED**		**11**	**9**

ANCs – Advanced practice nurse clinicians
ED – Emergency department
HCW – Healthcare workers
HDU – HAZMAT decontamination unit