A narrative review of secondary hazards in hospitals from cases of chemical self-poisoning and chemical exposure
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Secondary hazards are an important consideration when dealing with both self-poisoned and chemically contaminated patients. Secondary exposure of hospital staff following the admission of a poisoned patient is relatively rare but potentially serious. Risks usually arise from chemical conversion of a deliberately ingested toxic substance and subsequent offgassing, but there may be toxic substances on the victim or their clothing. Surface contamination is a more common concern in cases where patients have been exposed to chemical releases. This paper presents a narrative review that considers some of the more commonly encountered toxic chemicals and situations that may present secondary hazards in hospitals. Risks to staff can be lowered by reducing the potential for, and duration of, exposure wherever possible. Good communication with the first responders at the scene, consultation with experts, decontamination and use of personal protective equipment, together with regular training, can minimize risks in the hospital environment. *European Journal of Emergency Medicine* 20:304–309 © 2013 Wolters Kluwer Health | Lippincott Williams & Wilkins.

**Introduction: chemical exposures**
Exposure to toxic chemicals presents an acute risk and can also present secondary hazards to others away from the scene of exposure. This paper discusses such secondary risks and how they can be assessed and managed by the staff of hospital departments. A large number of toxic chemicals exist and storage and transport of such chemicals is commonplace. Chemical releases may be unintentional, and can occur in domestic and industrial settings or during transportation. The release of chemical agents may also be deliberate. Burgess [1] observes that ‘...incidents include airborne releases of gas and vapour, spills of solid and liquid material, and explosions and fires resulting in chemical release to the environment.’ Incidents leading to the potential or actual chemical contamination of healthcare facilities are not uncommon and containment and management within a hospital department is recognized as a particular issue during mass casualty incidents. Most chemical incidents involve relatively few casualties, but even one contaminated patient can pose a secondary risk to the attending staff. Chemicals stored and used within hospitals themselves also have the potential to cause disruption.

Self-poisoning is managed on a regular basis in emergency departments (EDs); consequently, it is a more familiar scenario than a chemical accident for emergency medical teams. The most common method of self-harm principally involves ingestion of a potentially toxic compound, although other routes of exposure such as inhalation or dermal exposure may also present.

Hospital staff may find themselves treating patients and responding to chemical exposures at short notice, without prior indication of the presence of contamination or any knowledge of the chemical involved or its toxicity. The provision of medical care within an ED may be disrupted because of the actual or potential chemical exposure of the hospital personnel and patients. Perceived risks may cause as much disruption as actual risks, and there are cases where odour-mediated psychological responses have disrupted ED function: strong or unpleasant odours from chemically contaminated patients can affect hospital staff, even if chemical concentrations in the air are below levels normally considered injurious [2].

Well-prepared and informed responders are better able to manage secondary hazards, and it is particularly important to promote understanding of chemical hazards in those working in health and emergency services. This paper presents a narrative review, discussing some of the more commonly encountered toxic chemicals and situations that may present secondary hazards in hospitals. It then outlines practical considerations faced by the staff when dealing with contaminated patients; resuscitation, inter-agency communication, chemical analysis, risk assessment, decontamination of patients, use of personal protective equipment (PPE) and the importance of training have also
been discussed. The paper concludes by presenting general principles for hospital staff dealing with chemical contamination incidents.

Judging secondary contamination risk

Important characteristics of chemicals when judging their potential to give rise to secondary risks include toxicity, latency, persistence and transmissibility [3–5]. The US Agency for Toxic Substances and Disease Registry considers there to be little or no secondary contamination risk associated with gases (such as carbon monoxide and amines), vapours (unless they condense to a liquid state on clothing or skin) and substances with no serious toxicity or skin absorption (such as motor oil) [6]. Low-toxicity chemicals are unlikely to present a significant secondary risk, but those with irritant properties can still pose problems: for example, although CS/pepper spray is considered to be a short-acting agent posing minimal risk, recent case reports demonstrate that it can cause secondary effects in the ED [7–9].

A substance poses a risk of secondary contamination if it is both toxic and likely to be carried in the body or on the clothing, skin or hair of victims in sufficient quantities to threaten others. Patients who have only been exposed to gases are likely to pose a reduced secondary risk, but it is still possible for them to exhale volatile agents. This may depend upon close proximity: those managing the patient’s airway are most susceptible. In cases where exposure was by ingestion, such as in many cases of self-poisoning, the risk of secondary exposure is greatest when the substance involved reacts with acids or moisture. In these circumstances, risks arise from the secondary release of toxic gases (from contaminated bodily fluids and/or offgassing from the body), contaminated vomitus and other body fluids and the presence of residual chemicals on the patient’s clothing or body. Toxic compounds may continue to be produced even after death, when enzymatic physiological processes cease. Table 1 presents three common poisons that present secondary risks after ingestion.

Incidents involving occupational and environmental exposures to toxic chemicals are more likely to present secondary risks to responders than cases of self-poisoning from inhalation and ingestion because of the increased likelihood of surface contamination. Substances that present the most serious risks from secondary contamination include highly toxic liquids and solids or finely divided solids, in which the risk is linked to the toxicity and persistent nature of the chemical substance.

Other commonly encountered chemicals may present secondary risks; Edkins et al. [10] observed liquefied petroleum gases and pesticides (such as the insecticide paraquat) as being among them. Mercury, arsenic, organophosphates/carbamates, strychnine and volatile organic solvents can also pose secondary threats. Chemical warfare agents such as hydrogen cyanide, chlorine, phosgene, organophosphates and CS gas have common civil applications. Substances such as mustard gas, organophosphates (e.g. sarin), phenol and phosgene, all of which may evaporate from heavily contaminated casualties, have the potential to give rise to delayed effects of a severe nature and cause acute effects. This may require those suffering from secondary exposure to be kept under medical observation or may lead to evacuation of hospital departments and their unavailability for routine use for some time. The general principles of chemical, biological, radiological and nuclear response remain true when dealing with chemical exposures that are not related to deliberate release scenarios [4]. The common form, important characteristics, routes of exposure and potential to present a secondary hazard are well documented for a number of toxic chemicals, as is the emergency medical response and management [6,11,12].

Resuscitation

Resuscitation may be required in both the prehospital and hospital setting. If a patient requires resuscitation following dermal exposure or ingestion of a chemical, there is a potential risk of exposure to chemical residues on the face and around the mouth. Inhalation of toxic gas on the patient’s breath (e.g. evolved following the reaction with stomach acid) may also present a risk. Consequently, mouth-to-mouth and mouth-to-mask ventilation should be avoided. General advice (primary emergency medical support is beyond the scope of this paper but is summarized in detail by Baker [13]) for professional responders with regard to resuscitation is as follows:

1. If the patient stops breathing, and no advanced life support equipment is available, resuscitation should be started using bag-valve-mask or bag-valve-laryngeal mask ventilation. Both these ventilation methods can be performed while wearing appropriate PPE. Ambulance personnel should refer to their organization’s operational procedures for resuscitation guidance.

2. If the patient is unconscious, the airway should be secured as soon as possible using an endotracheal tube. Ventilation should then proceed using an appropriate oxygen/air mix delivered by a portable gas-powered ventilator or self-reforming bag. Portable gas-powered ventilators are preferable, freeing both the operator’s hands for management of the airway.

3. Mechanical ventilation equipment should be isolated after use until scientific advice on disposal/decontamination is received.

Communication

Factors that can complicate the hospital response to chemical casualties include limitations in the information initially available, both from patients and emergency responders; poor communication and coordination.
between responders and healthcare staff before arrival of patients at facilities; and patients self-presenting at an unprepared hospital.

Unsubstantiated reports of chemical contamination can lead to the unjustified closure of EDs because of fear of the unknown, as can an initial over-reaction to the presence of a ‘chemical’. It is important that communication between prehospital and hospital practitioners is clear and consistent as there is scope here for inaccuracy to generate an inappropriate response at the ED – a situation that may be exacerbated in some cases if inexperienced staff are the recipients of courtesy calls from members of the emergency services [14]. Equally, personnel may not be aware of a chemical in the absence of obvious indicators, such as smell or immediate adverse health effects. Further information and expert advice can give a fuller understanding of the risks involved and rationalize the response.

Information about incidents is best obtained from the responding emergency services, which are present at the scene. UK Ambulance services now have Hazardous Area Response Teams; they are trained and equipped to work alongside fire and rescue services in the ‘hot zone’ (inner cordon) of major incidents [15]. In addition, the East Midlands and Yorkshire and Humber regions have hazardous medicine paramedics who provide an on-scene liaison with public health professionals in the Health Protection Agency (HPA) [16,17].

The UK National Poisons Information Service provides toxicological advice concerning the clinical management and treatment of poisoned patients. Hospital staff will be familiar with this service but may be less familiar with the role of the HPA, which should be contacted by hospital staff in cases where incidents may put other members of the public at risk.

The HPA’s Centre for Radiation, Chemicals and Environmental Hazards operates a 24h on-call service and provides information on specific chemicals, their public health implications and decontamination. The HPA is alerted by, and liaises with, emergency services when chemical incidents occur, which have the potential to affect public health. Hospital staff are able to contact the HPA directly for information and advice when dealing with chemical incidents or cases of self-poisoning.

**Chemical analysis**

Information from the scene is of particular value when a chemical’s identity can be confirmed; this can help in risk assessment and decision-making with regard to decontamination, use of PPE and medical management. Hospital laboratories are unlikely to be able to analyse samples of chemical contaminants – in any case, staff are advised not to risk moving hazardous chemicals through a busy working hospital. Any chemical sampling and analysis in the UK is most likely to be undertaken at the scene by the Fire and Rescue Service ‘Detection,
Identification and Monitoring’ capabilities. Off-scene sampling and analysis may be carried out under the auspices of a multiagency Air Quality Cell (coordinated by the Environment Agency in partnership with the HPA). In rare cases, third party or commercial stakeholders may undertake sampling and analysis.

Risk assessment
Risk assessment is integral to the identification and management of secondary contamination risks. As discussed above, information from emergency responders and chemical experts is invaluable when establishing what precautions are required, such as the need for decontamination and the use of PPE. The clinical condition of patients is also a key indicator of any potential secondary risk [2]; however, toxicidromes are not widely recognized or used across European Union (EU) Member States and standard documentation detailing chemical injury and clinical management is not widely available [3,4].

If the patient is asymptomatic or has mild symptoms of exposure, it is less likely that there will be a significant risk to the responders. However, an asymptomatic patient is not a guarantee that there is no secondary risk; health effects may be delayed. It is important to recognize that there may be cases in which patients have the external appearance of well-being while being contaminated by a potentially harmful substance. The reporting of symptoms by persons who have come into contact with a patient before admission is indicative of a potential secondary risk.

Limited information often prevents an initial risk assessment from being undertaken with any degree of confidence; the importance of effective communication is discussed in the previous section. The typical response of an unprepared hospital is a combination of initiating treatment without prior adequate decontamination and closure of the ED, while implementing relevant plans and establishing the correct protocols for proceeding.

Decontamination
Daugherty [18] argues the case for critical care providers to be aware of the principles of decontamination: first, during an incident, they may be reassigned to emergency response areas of a hospital; second, they must be aware of the possibility of inadequate decontamination of patients being transferred to critical care areas. This is a particular consideration in cases where patients self-present or when emergency services have been unable to undertake adequate prior decontamination, such as during rapid-onset mass casualty scenarios when their capabilities may be exceeded. Commenting in relation to the sarin gas attacks, Baker [13] and Daugherty [18] observed that secondary exposure (and its consequences) was likely to be proportional to the length of time spent in contact with contaminated persons and the patient’s initial level of exposure: staff in the intensive care unit showed higher rates of symptoms compared with those in the ED.

The presence of a chemical on a patient’s skin, hair and clothes indicates the need for decontamination to reduce the risk of secondary exposure. Standard guidance is for patients presenting from chemical incidents to be kept out of the ED for decontamination. Decontamination not only reduces the risk of secondary contamination of the healthcare staff and facility to maintain safe ongoing hospital operations but also prevents ongoing exposure of the affected patient.

Ideally, casualties should be decontaminated at the scene of an incident. In a best-case scenario, those contaminated are decontaminated at the scene of an incident by the emergency responders or upon arrival at a forewarned hospital that has pre-emptively setup decontamination facilities and is able to decontaminate contaminated patients before their admittance for treatment. In a best-case scenario, secondary contamination does not become an issue because any contamination is recognized and dealt with at an early stage, although recognition can be more difficult in cases of poisoning by ingestion.

Decontamination following toxic chemical exposure should include both removal of contaminated clothing and decontamination of the victim’s skin. There is a limited evidence base for determining the most effective method of decontamination [19,20]. Although dry decontamination may be appropriate in some situations, wet decontamination is the most feasible strategy in a mass casualty situation [18]. Default decontamination measures, appropriate to the majority of chemical exposures, are the removal (and double bagging) of contaminated clothing and possessions, removal of any excess powder (if present) and application of the rinse-wipe-rinse principle. This principle is based on the flushing of exposed skin and hair with copious amounts of water and the use of soap and water with the addition of simple procedures such as the use of a wash cloth (which recent studies have shown to be more effective than the use of soap and water alone [21]). Exposed or irritated eyes should be irrigated with plain water or saline.

Decontamination should be undertaken in a ventilated area, and personnel should wear full PPE. Ongoing communication in terms of prior decontamination and its adequacy is important as patients are transferred between locations (both preadmission and postadmission). Once a casualty has been decontaminated, it is unlikely that they will present a significant secondary contamination threat. External decontamination will not reduce the risk of exposure to toxic gases present in exhaled breath, or evolved from vomitus (in cases of ingestion), and this must be considered, although the risk
of secondary exposure from a single patient’s exhaled breath or vomitus is likely to be very low.

Although decontamination should ordinarily be undertaken outside of the ED, there may be rare cases in which the risk to an ED is considered minimal and that posed to a patient from delaying treatment is considerable. In these circumstances, Clarke [22] suggests that clinical judgement may need to override clinical guidelines while minimizing the impact to staff and other patients.

**Personal protective equipment**

Together with decontamination, the correct use of appropriate PPE, through staff awareness and training, mitigates the risks to healthcare staff associated with secondary contamination. Emergency medical responders should wear individual protective equipment in cases in which a persistent chemical has been released (i.e. where a chemical hazard exists). The UK Department of Health issued chemical personal protective equipment (CPPE) and decontamination tents to all ED and acute ambulance trusts in 2002. The NHS Structured Approach to Chemical Casualties [23] was also provided for training in use of CPPE and decontamination techniques (rinse-wipe-rinse). CPPE for use by medical staff who come into contact with patients includes chemical-resistant clothing and air-purifying respirators. It is important that staff have received appropriate training on the wearing and functions of protective clothing in advance of incidents.

**Training**

Although some papers indicate that deficiencies in training and preparedness have been better addressed in recent years [24], others indicate that problems remain [25,26]. Recent European studies to evaluate the preparedness of the EU Member States towards medical mass emergencies following chemical and radiological emergencies concluded that involvement and competencies of staff was lacking and that this could be related to the rarity of such events [27]. When considering both small-scale and large-scale incidents, a consensus remains that a regular, repeated programme of training and exercising is vital to keep skills up to date and ensure that hospitals are able to properly manage chemical incidents; this is corroborated by the lessons identified in continuing reports of incidents and ill-preparedness. Scales of required competencies have been drawn up for UK ED staff to form the basis of training for all staff in this section of hospital practice [4] and the HPA has published guidance on clinical management in chemical, biological, radiological and nuclear incidents [12].

The provision of training of hospital medical responders differs between EU Member States and collaborative training initiatives organized between responders and national chemical experts are encouraged. The reports of the EU-funded Mash project (MASH-casualties and Healthcare following the release of toxic chemicals or radioactive materials) [28] are a useful resource when considering ED training requirements: the project recommended important areas for chemical and radiological training and identified existing guidance, stating that the management of toxic trauma should be integrated with established trauma training programmes, such as the Advanced Trauma Life Support course model. The project concluded that cross-EU guidelines and a standardized curriculum for chemical casualty reception and management remain desirable; precedent models are already in place in some member states such as France.

**General principles for the responding hospital staff**

The considerations discussed above inform a set of general principles for responding hospital staff. The only practical way of ensuring that an ED does not have to shut during a chemical incident is to ensure that any individual exposed to a chemical is not permitted to enter until thorough decontamination has taken place, preferably at the site of exposure but, if necessary, in an isolated area within the ED itself (preferably outside the actual department, e.g., on the ambulance rank).

The following steps are recommended for staff dealing with chemical contamination:

1. Seek advice on appropriate PPE as soon as possible.
2. Know where your CPPE is kept and what is available.
3. Know about your hospital’s emergency plan and your role in it, and how to escalate an incident.
4. Seek advice as to what decontamination of hospital equipment and facilities is necessary, and know where to go in order to obtain this advice before an incident occurs.
5. If specific equipment is used when treating a contaminated patient, ensure that this is logged and that the equipment is not reused without first assessing whether decontamination is necessary.
6. Toxicity may increase in confined spaces – if undertaking decontamination indoors, consider ventilation of clinical facilities early in the response and the rotation of staff involved in treatment. Before considering ventilation, it is important to establish the destination of any vented gas and assess the risks to surrounding properties and the wider public. If the ED air conditioning or ventilation systems are connected to the rest of the hospital, then it may be advisable to switch these off. However, an independent air conditioning system should be kept running as it will improve the ventilation of the ED and help to minimize concentrations of airborne substances.
7. Where there is a possibility of risk to others, ensure that the patient is treated in an isolated bay.
8. Every ED should have a designated area/room that can receive contaminated casualties in the case of chemical exposure. This should be situated in an
area of the ED that does not necessitate the patient having to enter other areas of the ED and thus put other patients at risk.

Conclusion
Secondary hazards are an important consideration when dealing with both self-poisoned and chemically contaminated patients. The effects of chemical exposure depend on the specific nature of the contaminants and the duration and type of exposure. Risks to staff can be reduced by reducing the potential for, and duration of, exposure wherever possible. It is important for all responders to protect their own health first and not put themselves at unnecessary risk. Decontamination should not impinge on treatment and both processes should be carried out whenever possible. This may conflict with the need for staff protection in cases in which hospital responders are caught unprepared. A common position is that, until there is certainty about the nature of any chemical involvement, a precautionary approach is advisable and appropriate measures should be taken to protect the staff, other patients and facilities from the risk of contamination.

Acknowledgements
The authors acknowledge the kind assistance of Dr David Baker and Dr Sarah Finlay in reviewing later versions of the manuscript. J.S.E. takes responsibility for the paper as a whole.

This article was developed from two reports of a cyanide poisoning case study that were published by the HPA in in-house publications. James Stewart-Evans (HPA) and Andrew Sharman (NUH) met in 2007 to discuss the incident and agreed to produce a paper on secondary contamination in cases of poisoning that was suitable for a wider readership.

Conflicts of interest
There are no conflicts of interest.

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