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Review Article

Medical Intervention in terrorist attacks with chemical warfare agents: over ten years since the sarin gas terrorist attacks in Japan (Part 2)

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ABSTRACT

After the September 11 (2001) terrorist attacks in the USA and the subsequent mailing of letters contaminated with *B. anthracis* spores, a high perception of risk has become noticeable regarding the possibility of attacks with weapons of mass desctruction, particularly by groups associated to the Al Qaeda terror network. For this reason, the medical personnel –both extra- and intrahospitalary– has become concerned about how to act and perform in this type of events. In the case of chemical warfare agents, the guiding principles of medical support are based on the experiences and on the lessons learned by the personnel that dealt with the sarin terrorist attacks in Japan in 1994 and 1995. The present paper aims at delving deeper into these lessons and findings of over ten years ago, bearing in mind that any and every medical service and organisation should adapt them to their particular environment, situation and characteristics.

Key Words: *Chemical terrorism. Chemical warfare agents. Emergency medicine. Decontamination.*

RESUMEN

Actuación sanitaria en atentados terroristas con agentes de guerra: más de diez años después de los atentados con sarín en Japón (2ª parte)

Tras los atentados del 11 de septiembre de 2001 en EE.UU. y, sobre todo, desde los envíos de sobres con esporas de carbunco, existe una alta percepción del riesgo sobre posibles atentados con armas de destrucción masiva por grupos asociados a la red terrorista Al Qaeda. Esto ha llevado a que el personal sanitario extrahospitalario y hospitalario se interese sobre cómo debería ser su actuación en este tipo de incidentes. En el caso particular de los agentes químicos de guerra la base de la actuación sanitaria son las lecciones aprendidas por el personal sanitario que participó en los atentados terroristas con sarín que tuvieron lugar en Japón en 1994 y 1995. El presente trabajo intenta profundizar en estas lecciones aprendidas hace ya más de diez años, teniendo en cuenta que será cada servicio y organización sanitaria el que deberá adaptarlas a su situación y características particulares.

Palabras clave: *Terrorismo químico. Agentes químicos de guerra. Medicina de emergencias. Descontaminación.*

INTRODUCTION

Part I of this paper consisted of an analysis of basic aspects of medical intervention in the event of terrorist attacks with chemical agents, such as the coordination of bodies involved in the handling of the incident, the correct use of personal protective equipment (PPE), characteristics and limitations of the identification and detection systems, as well as the importance and difficulty posed by differential diagnosis and triage. This second part will continue to analyse other equally important aspects, as has been shown by the lessons learned by the medical intervention in the sarin gas incident in Japan and other incidents involving chemical agents.

ANTIDOTES AND MANAGEMENT OF MEDICAL RESOURCES

In addition to the resources needed for support and symptomatic treatments, the great unknowns –which can be of critical significance in the event of chemical agent attack – are the antidotes (see Table 1 in part 1). Antidotal treatment for neuro-

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toxic agents involves atropine, an oxime and a benzodiazepine as an anticonvulsant. One of the main disadvantages is that a wide-ranging oxime has yet to be developed, that is, an oxime which is fully effective against any warfare neurotoxic agent or anticholinesterasic organophosphorous compound[1]. HI-6, the oxime with the most wide-ranging mechanism of action, is only commercially available in special self-injectors known as double chamber injectors, which are not yet developed to the full. The non-availability of a wide-ranging oxime and the subsequent ineffectiveness of available antidotal treatments has led to the research and development of what is known as "modern" treatment, based on the use of sweepers[1,2]. Compared to the levisites, Dimercaprol, also known as BAL (British Anti-Lewisite) has shown some efficacy in counteracting systemic effects, especially in the bone marrow[3]. Hydroxocobalamine or the combination of sodium nitrite and sodium thiosulphate are the antidotal treatments available in Spain for cyanide agent intoxication[4,5]. Physostigmine is also indicated for cases of serious BZ intoxication, although it has a narrow safety margin[6]. Although the ideal scenario would be administration of the antidotal treatment by medical personnel, the first persons on the scene should be fitted with self-injectors for rapid intramuscular administration of antidotes against neurotoxic warfare agents which can bring about death in a few minutes. This need is fundamental in the case of soman intoxication, as the acetylcholinesterase inhibiting this agent undergoes a rapid (2-4 minutes) 'aging' process, after which the oximes become ineffective[7]. The Iran-Iraq war experiences have shown that a fast administration of antidotal treatment means a higher probability of recovery with no sequelae[8].

On the day of the sarin gas attack in Tokyo there were sufficient quantities of atropine but not of pralidoxime, mainly stored in rural area hospitals where agricultural activities increase the risk of intoxication by organophosphate insecticides[9]. Nobody, however, was capable of moving such reserves to the Tokyo hospitals. St. Luke International Hospital was fortunate enough to have a good stock of pralidoxime (100 ampoules) and the hospital's pharmacy service was able to rapidly obtain more[10]. This situation highlights the need to establish a system to manage medical resources in the event of attacks with chemical weapons of mass destruction.

In the USA, following the attacks of September 11th 2001 (9/11), the Strategic National Stockpile (SNS) was created on the 1st of March, 2003 for the local and state-wide supply of antidotes, antibiotics and vaccines, among others, in the event of mass destruction chemical attack and other public health emergencies[11,12]. The SNS enables local and state supply of medical resources in less than 12 hours, via its storage facilities strategically located all over the country to ensure the minimum period can be met. The SNS is nothing less than an extension of the National Pharmaceutical Stockpile (NPS) created in 1999 which was able to dispense medication and medical supplies to New York City on 9/11 less than 7 hours after the attack[13]. Since its creation, the SNS has been used to solve non-terrorist public health problems. These real operations coupled with the simulations carried out to date have enabled the correction of errors in the composition of stockpiled assets, in the activation protocols and in the transport of the medication and supplies requested[15-19].

Although management of resources on a national level is important, resources must initially be managed at a local level[13-15]. In the US the pharmaceutical dispensing service at Maimonides Medical Centre, which played a central role in 9/11 and the incidents with anthrax spores, has designed a Pharmacy Team to respond to Emergencies (PTRE) prepared to manage medical resources required in the event of chemical weapons incidents[20]. Lyophilized atropine storage systems have even been designed at a hospital level enabling the fast preparation of pre-filled syringes by the pharmaceutical department[21].

EFFECTS AND PSYCHOLOGICAL ASSISTANCE

Both terrorist attacks with conventional weapons and those with chemical weapons result in a high number of casualties with psychological effects such as: direct victims of the weapons, people in the area under attack not directly affected by the weapon, victim relatives and intervening personnel[22-25]. Psychological effects usually persist even years after the event. The aim when using chemical weapons is not only to intoxicate people, but also to spread fear and panic among the population, in the same way that in a military setting the aim is to undermine the morale of the troops. Several studies published in biomedical journals show that in incidents involving hazardous substances the victims suffer more stress and psychological effects[26-30]. A recent study polled victims who 8 to 40 days previously had been exposed to hazardous substances; it showed that the somatization syndrome was significantly higher compared with the control group[31]. One of the first cases published which showed the importance of psychological effects in hazardous material incidents took place in 1973: a ship moored in a port in New Zealand was unloading barrels containing an organophosphorous compound, when a dock worker noticed a strange smell and a label on the barrels reading "poison"[32]. Word of mouth resulted in 643 people seeking medical help, although it is believed that only 241 dock workers could have actually had direct contact with the barrels.

In the Tokyo attack in 1995 more than 5,000 people went to the hospitals and medical centres but less than 20% showed clinical signs of sarin gas intoxication, whereas the rest had undergone subclinical exposure or presented with symptoms of a psychogenic origin[33]. The psychological effects persisted even 5 years after the attack[34]. Likewise, during the Iran-Iraq war, the cases of psychological "sick leave" hindered differential diagnosis made military by medical personnel due to the so-called "worried healthy", ie troops with no clinical symptoms or signs of intoxication but with a high degree of anxiety and due to the so-called "worried sick", troops who, without having been exposed to the agent, presented with intoxication symptoms of a psychogenic origin[8].

During the Gulf war in 1991 the Israeli government provided civilians with nuclear, biological and chemical (NBC) defence masks and self-injectors with antidotes against neurotoxic agents, which led to cases of asphyxia due to misuse of the mask under stress situations[35] and cases of atropine intoxication when, on hearing the alarms of Iraqi scud missile attacks, people believed they suffered intoxication by neurotoxic agents[36]. Likewise, during this war US military personnel suffered panic attacks, hyperventilation and even inability to put on the NBC masks despite having had no problems during the training sessions, whenever the alarms for false positives from the detection devices were activated[37].

Competition among the media can trigger dissemination of sensationalist information, fostering a fear of the unknown and spreading panic among the population[38-41], which can aggravate the situation in the medical centres[42]. The method of communicating information by public authorities can have the same effect. For instance, in June 2005, following a fire in a dairy factory in New Zealand, the firefighters' spokesman stated to the media his concern that the combination of caustic soda and sulphuric acid stored in the plant could produce mustard gas, which is completely false, but which nonetheless created social alarm among the population living close to the area of the incident[43]. It is important that both the first personnel on the scene and the medical personnel acting as spokespersons before the media bear in mind that the public's perception of risk will be affected by the information given. In fact, some authors report that the public finds information provided by medical personnel more credible than that given by other spokespersons[44-46]. The so-called "Giuliani model" of press conference which yielded good results in the anthrax envelope incidents after 9/11 was based, in part, on the Mayor of New York City passing the microphone over to his medical advisor to transmit confidence to the public[47].

VICTIM DECONTAMINATION

One of the most often mentioned lessons learned from the terrorist attacks in Japan has been the need to decontaminate not only the intervening personnel at their exit from the incident zone but also the victims. The aim is to end or reduce the contact between the casualty and the chemical agent and prevent secondary contamination[48].

In Matsumoto and Tokyo the underground workers, firefighters, policemen and medical personnel suffered secondary contamination upon contact with non-decontaminated victims[10,49-53]. Okumura et al[54] report that 9.9% of the first intervening personnel suffered secondary contamination during the Tokyo attack. Likewise, the casualties taken to hospitals in Tokyo and Matsumoto led to secondary contamination of the hospital staff[55-57]. At St. Luke Hospital approximately 23% of the hospital staff reported symptoms related to secondary contamination: 39.3% of auxiliary nurses, 26.5% of nurses, 25.5% of volunteers, 21.8% of physicians and 18.2% of administrative staff[10]. The most affected areas were the chapel, used as an additional area, and the Intensive Care Unit, the first due to poor ventilation and the second perhaps because it held the more seriously affected victims and was the area where those who had had presumably been exposed to the highest concentrations of sarin gas were taken[10]. On the other hand, the least affected area was the emergency department, perhaps due to its good ventilation and its entrance directly into the street which was frequently opened and closed. Both in the first personnel on the scene and the Tokyo hospital staff the effects were local and in some cases victims received antidotal treatment[55]. Only one underground worker died a few minutes after picking up a bag containing 600 grams of sarin at 35%[58]. In fact, the low grade of purity of the sarin used in Tokyo may have been the reason for fewer serious cases of secondary contamination[58].

It is important to bear in mind the rapid absorption by the skin of agents such as VX[59,60] or mustard gas, which is not detectable after 30 minutes[61], which would require the decontamination process to be performed as quickly as possible.

Decontamination products

One of the main problems posed by decontamination of personnel is the type of decontaminant to be used[62]. These decontaminants can act by detoxification, absorption, dilution or physical removal.

Some warfare chemical agents are lipophilic (eg. mustard gas) and initial decontamination with water can spread the contamination over a larger body surface area, increasing local effects and fostering the absorption and thus systemic effects. In these cases absorbent products should be used first (eg. Fuller's earth) which absorb the liquid contamination from the body surface area[63,64]. In fact, among the military NBC PPE complementary materials provided for soldiers is a mitten with absorbent material for emergency decontamination by the individual himself. In a civilian scenario this could translate as emergency decontamination with absorbent products by rescue teams or decontamination station staff, at the entrance to the affected area.

In the event of chemical agents in gas form at room temperature, removal of clothing and a water shower (or soap and water) should be enough, whereas in the case of solids or liquids, the water can dilute and spread the agent over the surface of the body[48,65]. When decontaminating, special care must be taken with substances that react violently to water (eg. cesium, lithium, potassium, sodium and rubidium, among others)[66]. For some authors the removal of clothing can mean a 75-90% elimination of the contamination[48,67-70]. However, the National Institute of Standards and Technology (NIST) reports that the type of clothing must also be taken into account, calculating it may only represent 50% decontamination in some cases[71]. Another added problem in clothing is that it must be removed by cutting it off, thus preventing contamination spread[66,72]. Phosgene and lewisite decompose rapidly in the presence of water or in highly moist environments[65,73]. In the case of victims by ingestion the risk of secondary contamination via vomiting must be taken into consideration.

Sodium hypochlorite at 0.5% is indicated for decontamination of victims of vesicant and neurotoxic agents, as it favours hydrolysis and the oxidation of the agents[74]. Concentrations of 1% have proven efficacious in the detoxification of mustard gas in contact times even under 5 minutes, exceeding the efficacy of some commercial decontaminants specifically manufactured for decontamination of warfare chemical agents[75]. Hypochlorite continues to act in the water collected from the decontamination process. The advantage of sodium hypochlorite is that it is an easily and readily available product, through the pharmacy services. There are commercial products of proven efficacy for decontamination of chemical warfare agents but their expiration and high cost are disadvantages to be taken into account. The time spent showering or washing depends on each specific case (type of agent, extension of the contamination, characteristics of decontamination station and decontaminant used, among others)[66,76], but for practical reasons some authors recommend 5-6 minutes per victim[66,72].

Commercial decontamination equipment is based on the application of the decontaminant and its rapid aspiration rate. These devices were designed for decontamination in the event of nuclear or radiological incidents, as they spray a chelating substance – usually Schubert's solution – to then absorb the complex chelates formed with radioactive particles. Their efficacy in the case of chemical contamination has not been proven,; its cost and maintenance are also factors to be taken into consideration.

In open wounds and eyes hypochlorite must not be used; it is best to use saline solution. Decontamination products are currently being developed based on endogenous enzymes (eg. Mutant butylchlinesterases) with a large detoxifying capacity and which could be applied to open wounds[77].

The possibility that the physical-chemical characteristics of chemical agents can change- thus hindering the decontamination process- must also be taken into consideration. This is the case with "thickening", involving the addition of an acrylate to increase the persistence of the agent, also helping it to adhere to surfaces, rendering the decontamination process more difficult[78]. This is also the case with "dusty agents", particles which act as a continuous release of the agent, increasing its persistence and hindering decontamination.

Decontamination stations

Although we shall not go into much detail as to the steps involved in victim decontamination, which depends on the intrinsic characteristics of each commercial model, the decontamination lines of outpatient casualties should be separated from those of non-outpatient victims who must be transported on stretchers[79]. This last task means extra work for the station staff. Various commercial manufacturers currently provide decontamination stations on tracks or rollers to help move along patients on stretchers (Figure 1).

In the beginning this process was carried out manually by station personnel, which meant at least 30 minutes per non-outpatient victim and considerable physical effort on the part of the staff. Modern stations have allowed this time to be reduced to around 10 minutes, demanding much less effort from the staff. Stations should be equipped with tents to protect the victims' privacy, particularly when in the presence of the media. Furthermore, in order to avoid hypothermia, room temperature should be matched with that of the water in the showers.

An additional problem faced by decontamination stations are active agents or toxic metabolites left in the waste water. Some stations are fitted with water, and even air, collection systems, in which pressure differences force the water or air to pass through filters. This water collection system might logically become saturated and, in any event, once the decontamination process is complete, the area where the station was erected might require more aggressive decontamination and control.

Contamination Control

Some intervening units perform a control process at the entrance and/or exit of the decontamination station. In addition to the problems mentioned in Part I of this paper on false positives and false negatives yielded by detection devices, the performance of a control on the entire body surface area of a victim can take some time, which from an operational perspective is not very effective, being much simpler and more practical to decontaminate all those who hail from the affected area.

Pre-hospital decontamination

The US Environmental Protection Agency (EPA) and the National Institute for Occupational Safety and Health (OSHA) recommend the division of the affected area into 3 zones: hot, arm and clean (also known as cold zone)[80] (Figure 2). The hot zone is the area directly affected by the chemical agent. The warm zone is so-called because, despite initially being a clean area, it is where the decontamination task will be carried out, which means a concentration of personnel and/or materials which may be contaminated. The name ‘warm zone’ should be taken seriously and, in terms of protection, must be considered a hot zone. Computer systems such as ALOHA® or PEACWMD®, among others, are useful in quickly determining the danger areas and hot zone boundaries based on the information available on the agent, the type of incident and meteorological conditions. The exit from the decontamination station marks the boundary for the clean zone. Within the clean zone another boundary must identified - the so-called support zone -, where all supplies and materials will be held. This boundary usually depends on the extent of the resources deployed.

Only the State Guard and Police Force, firefighters and rescue personnel should enter the hot zone. These, depending on action protocols, may or may not be accompanied by medical personnel. Behind the decontamination stations, that is, following on from the Warm Zone, are the Advance Medical Posts and the Medical Evacuation Centres. Most of the medical staff will therefore be located at the end of the decontamination station to enable them to treat the victims without the need for PPE. However, before the victims enter the decontamination area itself, they must pass through a primary triage area and an emergency medical treatment station designed to stabilize the patient before entering the decontamination zone. The medical staff in both areas must wear PPE, with the resulting restriction on intervention capacity.

Figure 1. Decontamination line of non-outpatient victims. Station personnel uses Level B protection according to the classification of the US Environmental Protection Agency (EPA).

Hospital decontamination

Although all those exiting the hot zone should ideally have been decontaminated, the truth is that by the time the hot and warm zones are set up and controlled, victims will have arrived or be arriving at the hospital; hence the importance of coordination centres to inform and alert nearby medical centres in order to control arrivals and deploy, or in absence of means, to improvise decontamination systems[45-81]. In the Tokyo attack, 35% of victims treated at St. Luke Hospital arrived of their own accord, not necessarily entering via A&E, but by any of the three hospital entrances[10,82]. Control and cordoning-off of the underground stations took about 30 minutes by which time many victims had left the hot zone by their own means or in private vehicles or taxis[54,82,83]. In these cases it is imperative that security personnel control and direct the access to hospital by people and ambulances. The coordination centres should also organize transport to hospitals to enable

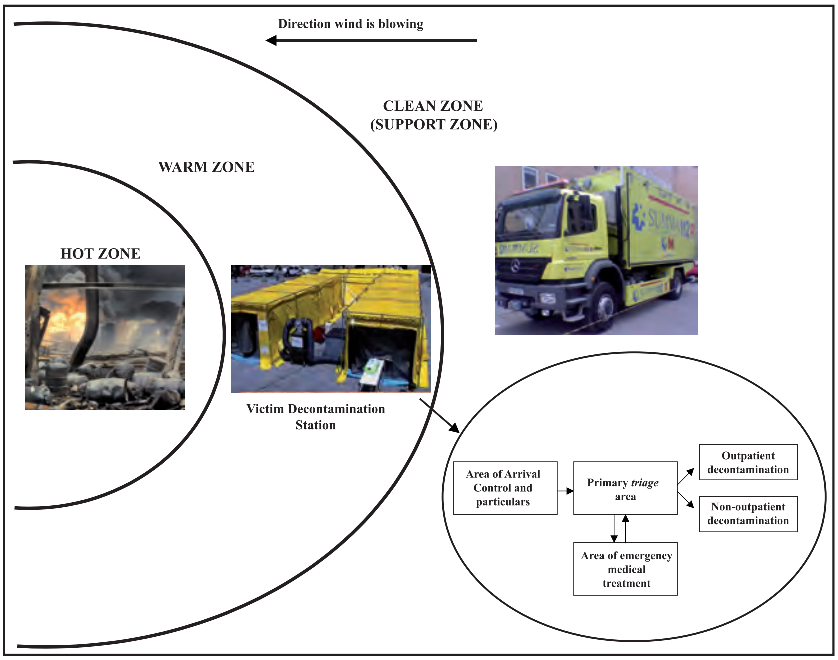

Figure 2. Zones into which the intervention area is divided in the event of a chemical agent accident or attack. More details are included on the victim decontamination station.

the ambulances to arrive at suitable areas for victim reception. On their part, among their disaster action plans, hospitals must have specific action protocols for chemical agent incidents covering all aforementioned aspects[62,67,84-90].

The structure of victim decontamination stations in hospitals should be similar to that of the warm zone, with a line for outpatient victims and another for victims on stretchers. Some hospitals have a permanent area fitted with showers to carry out decontamination, but the usual and most practical way is to perform this in deployable equipment outside the emergency department[45,68].

Use of PPE in hospital decontamination stations

Hospital staff coming into contact with the victims hailing from the affected area should follow the same PPE selection criteria as those explained in Part I of this paper. Nevertheless, the OSHA allows for the possibility of reduced protection levels due to possible contamination transferred to the hospital in the body, clothing and personal belongings being much less than that transferred to the warm zone adjacent to the hot zone. This will largely be due to the lower number of victims than in the warm zone and the volatilization and dissipation of the agent during transport to the hospital. In fact, a review of biomedical publications on chemical substance incidents suggests that the incidence of secondary contamination of hospital personnel by victims is low[55,57,89,91-105]. Despite incomplete data provided by the authors in some cases, secondary contamination is usually due to non-decontamination of the victims upon exiting the hot zone, or before coming into contact with hospital A&E staff. No netheless, in some cases provisional closure of the emergency department for decontamination has been required, which can be an added complication in the management of a mass casualty incident. Cases of secondary contamination have even been attributed to contact or exposure to the gastric content of individual intoxicated with cyanide salts or arsenic compounds[83,100]. Based on this information and on two models for predicting the level of protection to be worn by hospital decontamination personnel in the event of a chemical agent incident[106,107], the OSHA recommends the use of Level C with assisted ventilation filter masks with an assigned protection factor (APF) of 1000, that is, that the concentration inside the mask is 1000 times lower (0.1%) than the concentration of the agent in the air[72]. The filter must be combined with an HEPA (High Efficiency Particulate Air) filter to prevent the passage of solid particles. On the other hand, the OSHA reports that once the threat has been appraised, the hospital must assess the need to increase the level of personal protection. In fact, there have been some cases of secondary contamination of hospital staff by very volatile agents or gases at room temperature which should not pose a risk due to dissipation after a few minutes[98]. For this reason, at least the staff responsible for receiving the victims and guiding them through the decontamination station should wear the highest possible level of protection. Several authors, in agreement with the OSHA, recommend level C because Level B means added weight for the staff, that is, less agility and higher cost for the hospital in terms of acquisition and maintenance[66,79,83,97,108]. However, they all report that some situations may require higher levels of protection. For Baker[109] level C with NBC military filters is adequate protection as he believes that there are few possibilities that terrorists will develop new chemical warfare agents that are not adsorbed by activated carbon, which is a mistake given reports that the chemical agents of interest by terrorist groups associated or related to the Al Qaeda network are mainly industrial chemical products instead of 'classical' warfare agents[110]. Koenig[111] published an excellent article in 2003 entitled "undress and take a shower", he reflecting the difficulties of arriving at a consensus in the choice of level B or level C. The difficulties of purchase and maintenance of level B equipment for hospitals, as well as personnel training and the difficulty of wearing such kits, were ackowledged but it was also recognised that if, in some cases, 80% of the victims are to arrive at the hospital of their own accord without previous decontamination, level C equipment cannot be enough to protect the staff. Moreover, the Tokyo experience shows that several hours after an attack the identity of the agent may still be unknown, with no option left available for selection of the right filter[112]. Kirk et al[45] suggest that hospitals should have a group of people specially trained in the use of PPE's and the performance of decontamination processes, available round the clock. In this case, the personnel would indeed be prepared for working under level B protection.

Training

Before the response phase (during the incident) there must be a preparation phase in which the extra-hospital and hospital emergency plans are established and personnel is trained and tested by means of drills and simulations designed to detect intrinsic problems in each intervening unit or in each hospital[73,113]. Furthermore, suitable training in personnel chemical defence has proven to modify their perception of risk and instils a greater sense of duty[114]. After the 9/11 attacks the UK National Health Service (NHS) distributed 2,500 equipment kits which included PPE and a blow-up decontamination tent to health centres and hospitals al over the country. Several simulations were hold, highlighting problems with PPEs, especially of an ergonomic nature, likewise confirming the need for previous training of all the personnel to enable adequate use of the equipment[115].

CHRONIC AND LONG TERM EFFECTS

After a chemical agent incident a follow-up of victims and epidemiological studies of affected zones must be carried out in order to identify chronic and long term effects. Even years after exposure, victims of the Matsumoto and Tokyo attacks bear physiological and psychological sequelae[34,52,56,57,83,116-123]. There is also a certain amount of controversy as to whether the subclinical exposure to warfare neurotoxic agents (low concentrations with are not even sufficient to produce clinical symptoms or signs of intoxication) can lead to delayed neuropathy by organophosphates, similar to that induced by certain organophosphorous insecticides[7]. Thanks to the experience of Iranian physicians during the Iran-Iraq war we know today that mustard gas intoxications have important long term effects which may appear years after exposure, mainly affecting the respiratory system, skin and eyes[3].

CONCLUSIONS

Although since 9/11 there is a high level of perceived risk of the possible use of chemical warfare agents by groups related or associated with the Al Qaeda terrorist network, no attack has taken place to date. There have, however, been a number of attempts and, worst of all, it is clear that these groups are actively working to obtain chemical substances for use in terrorist attacks. The difficulty in obtaining 'classical' chemical warfare agents has turned their interest towards easily obtained industrial chemicals which, if used in a terrorist attack, could have catastrophic consequences such as those produced by the dispersion of methyl isocyanante in Bhopal (India) in 1984. This is why many analysts believe that the occurrence of a terrorist attack with chemical agents is simply a matter of time.

Despite the fact that the sarin gas attacks in Japan happened over ten years ago, the lessons learned by medical personnel are still current today and, in many cases, are yet to be implemented. It is important that each medical service and organization adapts these measures to their specific situation. Their incorporation of the protocols and action plans for both hospital and extra-hospital staff will help minimise the consequences of a possible attack with such agents. A new incident will bring new lessons to be learned to help improve medical intervention and remind us of the gulf which exists between theory and practice. What would be sad would be if the new lessons to be learned were exactly the same as those learned more than ten years ago in Japan.

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