DM

ORIGINAL ARTICLE

Preparedness for the evaluation and management of mass casualty incidents involving anticholinesterase compounds: A survey of emergency department directors in the 12 largest cities in the United States

James M. Madsen, MD, MPH, FCAP, FACOEM, COL, MC-FS, USA; Michael I. Greenberg, MD, MPH

Abstract

Objectives: *Anticholinesterases include carbamate and organophosphorus (OP) insecticides and nerve agents. Release of these compounds can flood emergency departments (EDs) with large numbers of poisoned victims and worried individuals. It was hypothesized that despite the focus of disaster preparedness on large metropolitan areas, EDs in these cities would still report self-perceptions of deficiencies in preparedness for mass casualty incidents (MCIs) involving these chemicals.*

Design and setting: *A secure and anonymous online survey was prepared and piloted, and E-mail invitations were sent to the physician directors of the 220 continuously staffed EDs in the 12 most populous incorporated cities in the United States.*

Results: *Forty-six ED directors could not be contacted despite repeated attempts. Of the remaining 174 directors, eight declined and 89 took the survey, for a response rate of 51.1 percent. Fewer than 20 percent were very confident in the effectiveness of their training, and only 4.9 percent were very confident that drills had given them the preparation that they needed. Only 45.7 percent of reporting hospitals had a board-certified medical toxicologist to help in such an emergency. Almost two-thirds (73.6 percent) of those familiar with the online Radiation Event Medical Management (REMM) module from the National Library of Medicine and the National Institutes of Health thought that a chemical counterpart to REMM would be either moderately or very helpful for MCIs involving anticholinesterases.*

Conclusions: *This study demonstrates that physician ED directors perceived marked deficiencies in their abilities to respond to this kind of toxicological emergency and suggests critical directions for remediation of these deficiencies.*

Key words: cholinesterase inhibitors, chemical terrorism, organophosphorus compounds, disaster medicine, emergency medicine, REMM, CHEMM

Introduction

Even before the Oklahoma City bombing and the release of the nerve agent sarin in Tokyo in 1995, the 1996 Khobar Towers bombing, the attacks on the US embassies in 1998, and the World Trade Center attacks of 2001, many hospitals recognized the consequences of failing to prepare for mass casualty incidents (MCIs) of low probability but high impact[1]; however, the terrorist events of the 1990s and 2001 lent new urgency to disaster preparedness.[2] Despite the promulgation by the Joint Commission of standards for hospital emergency management,[3] a 2003 report by the United States Governmental Accounting Office disclosed that most urban hospitals had developed emergency plans but had important terrorism-related deficiencies, especially in the areas of communication, training, drills, and equipment.[4] Although public health agencies[5] and government programs[6] are vital for disaster response, hospital emergency departments (EDs) will bear the brunt of the initial challenges of a disaster, because most MCI survivors will either be transported to EDs or report to EDs on their own.[7] The American College

DOI:10.5055/ajdm.2010.0035

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2010	**N/A**	**-**

4. TITLE AND SUBTITLE
Preparedness for the evaluation and management of mass-casualty incidents involving anticholinesterase compounds: a survey of emergency-department directors in the 12 largest cities in the United States

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Medical Research Institute of Chemical Defense 3100 Ricketts Point Road Aberdeen Proving Ground, MD 21010-5400

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Published in American Journal of Disaster Medicine, 5(6), 333-351, 2010., The original document contains color images.

14. ABSTRACT
Anticholinesterases include carbamate and organophosphorus (OP) insecticides and nerve agents. Release of these compounds can flood emergency departments (EDs) with large numbers of poisoned victims and worried individuals. It was hypothesized that despite the focus of disaster preparedness on large metropolitan areas, EDs in these cities would still report self-perceptions of deficiencies in preparedness for mass casualty incidents (MCls) involving these chemicals.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**19**	

of Emergency Physicians has urged emergency physicians to take active roles in hospital disaster preparedness, to communicate effectively before and during disasters, and to be prepared to triage scarce resources in disaster situations.[8]

Challenges from potential disasters are particularly intimidating in the realm of unconventional mass casualty weapons (MCWs), the so-called weapons of mass destruction (WMD): chemical, biological, nuclear, and radiological releases.[9,10] Toxic chemicals[11] are not only an important subset of unconventional MCWs[12] but also represent a danger from the inappropriate use of commercially available compounds.[13-16] One group of chemical compounds with a recognized potential for creating large numbers of casualties is anticholinesterase compounds, or cholinesterase inhibitors, which include carbamate and organophosphorus (OP) insecticides as well as the OP chemical warfare agents known as nerve agents.[17] These compounds inactivate the enzyme (acetylcholinesterase) responsible for the normal in vivo hydrolysis of the neurotransmitter acetylcholine after physiological end-organ activation; as a consequence, excessive cholinergic stimulation of end organs leads to hyperactivity and subsequent fatigue and failure of skeletal muscles as well as producing effects on smooth muscles and in exocrine glands and the central nervous system. The classic constellation of clinical findings from anticholinesterase poisoning is called the cholinergic toxidrome[17] and includes nicotinic receptor-mediated effects such as twitching, fasciculations, skeletal muscle weakness, and paralysis; and muscarinic receptor-mediated effects such as miosis, bronchospasm, hyperperistalsis, the production of copious secretions, seizures, and central apnea.[18,19] The inappropriate application of anticholinesterase pesticides or the intentional release of these pesticides or the even more potent nerve agents can generate large numbers of casualties, and the triage, diagnosis, decontamination, medical management, and disposition of these victims can overwhelm EDs, as illustrated by historical examples of OP-insecticide poisonings[20-22] and the infamous release of the nerve agent sarin in the Tokyo subway system.[23,24] The observations that anticholinesterase poisonings are relatively rare in many community settings and that the clinical presentation of such poisonings may be atypical in special populations such as children[25] may make initial ED diagnosis difficult. A recent consequence analysis of a hypothetical indoor release of sarin confirmed mild effects within minutes of release, with serious injuries and fatalities beginning about 20 minutes after release. It also reinforced the importance of the key emergency response challenges of (a) time factors relating to the short latent period, (b) high casualty rates, and (c) contamination issues.[26]

Determining the level of hospital and ED preparedness for disaster preparedness is not an easy matter; as Burstein[27] points out, tools designed to measure hospital preparedness exhibit high variability. Moreover, there is yet no universally accepted generic scoring system for disaster preparedness.[27] Nevertheless, surveys have evolved to become a popular, however flawed, means of attempting to assess the preparedness of hospitals and EDs for disasters, including chemical MCIs. Keim et al.[28] used a survey to investigate preparedness for chemical terrorism between 1996 and 2000 in a major US city and concluded that the hospitals studied were poorly prepared to manage chemical emergency incidents, including terrorism. A pre-9/11 survey of 224 hospital EDs in four northwestern states found that EDs "generally [were] not prepared in an organized fashion to treat victims of chemical or biological terrorism,"[29] and a smaller, contemporary, interview-type survey of hospital personnel in 30 hospitals revealed that 73 percent felt unprepared to handle a chemical weapons incident despite training being provided to nearly one-fourth of the participants.[30] WMD preparedness had been incorporated into hospital disaster plans in 27 percent of facilities. In 2003, a National Hospital Ambulatory Medical Care Survey found that although 85.5 percent of the approximately 500 US hospitals surveyed had plans for responding to chemical disasters, only 46.1 percent reported written agreements with other facilities; the survey also showed that drills for natural disasters occurred more frequently than for chemical events.[31] In 2002, Greenberg et al.[32] published the results of a 38-question questionnaire mailed to physician ED directors in the greater Philadelphia area to assess their preparedness for chemical and biological

terrorism; this survey disclosed deficiencies in written policies, interagency agreements, training and education, decontamination facilities, and antidote availability in the surveyed EDs. In the study by Greenberg et al., although two-thirds of EDs (66.7 percent) had written policies for dealing specifically with chemical and biological casualties and 59.2 percent of EDs had chemical agent- or biological agent-related drills in the preceding 3 years, 61.1 percent of respondents were unaware of any written policy for contacting governmental agencies in the event of a chemical or biological MCI, and 61.1 percent believed that hospital supplies of antidotes for these events were inadequate. Two British surveys from this period uncovered similar problems in the United Kingdom.[33,34] Later surveys[35,36] demonstrated continuing deficiencies in hospital and ED response in the US cities.

No study has specifically investigated the preparedness of EDs for MCIs involving the release of anticholinesterases. The hypothesis of this study was that despite the focus of disaster preparedness on large metropolitan areas, EDs in such cities would still report perceived deficiencies in preparedness for disasters, especially those in which large-scale releases of anticholinesterases might occur. The expectation was also that a survey of this kind could identify particular deficiencies amenable to changes in administrative or clinical policy, thus guiding remedial actions.

Methods

It was decided to survey physician directors of EDs in the 12 largest cities in the United States, and the US Census Bureau was consulted to obtain a list of the 12 largest incorporated cities in the United States as of July 1, 2008 (Ref. 37); these cities were (in the order of descending population) as follows: New York City, Los Angeles, Chicago, Houston, Phoenix, Philadelphia, San Antonio, Dallas, San Diego, San Jose, Detroit, and San Francisco. The *AHA Guide 2009* listed a total of 424 hospitals for these 12 cities (Table 1).[38] To be considered for inclusion in this survey, an ED needed to be located in one of these 12 cities, to be staffed 24 hours a day, and to have a physician director.

The initial survey questionnaire included an introductory demographics section and 60 nondemographic survey questions. The number of nondemographic items was reduced to 30, and the resulting survey was piloted among a group of 24 physicians, nurses, and governmental officials. It was submitted to an institutional review board (IRB #1) at the Drexel University College of Medicine under an exempt review application (Exempt Category 2) and approved as Protocol 18478. The final questionnaire consisted of an initial demographics section with four questions (A, B, C, and D) and then 30 numbered questions divided into six sections: (a) planning and communication (five questions, numbered 1-5); (b) decontamination, detection, and personal protective equipment (PPE; five questions, numbered 6-10); (c) training and drills (four questions, numbered 11-14); (d) capacity and staffing (four questions, numbered 15-18); (e) antidotes (nine questions, numbered 19-27); and (f) additional resources (three questions, numbered 28-30). An additional item at the end of the questionnaire allowed interested participants to provide open-ended comments. The survey was placed onto a secure online site

Table 1. The 12 most populous incorporated cities in the United States as of July 1, 2008 (Ref. 37): Distribution of 424 hospitals listed by the *AHA Guide*[38]

City	Number of hospitals
1. New York City, NY	89
2. Los Angeles, CA	49
3. Chicago, IL	51
4. Houston, TX	61
5. Phoenix, AZ	23
6. Philadelphia, PA	30
7. San Antonio, TX	36
8. Dallas, TX	36
9. San Diego, CA	18
10. San Jose, CA	5
11. Detroit, MI	15
12. San Francisco, CA	11

Table 2. Demographic data for responding hospitals and EDs	
A. In or near which city is your ED located?	
City	Percentage (n)
New York City	32.6 (29)
Los Angeles	9.0 (8)
Chicago	13.5 (12)
Houston	5.6 (5)
Phoenix	6.7 (6)
Philadelphia	10.1 (9)
San Antonio	7.9 (7)
Dallas	3.4 (3)
San Diego	2.2 (2)
San Jose	0.0 (0)
Detroit	4.5 (4)
San Francisco	4.5 (4)
B. How many beds does your hospital have?	
Beds	Percentage (n)
<50	0.0 (0)
51-100	2.2 (2)
101-300	47.2 (42)
301-500	24.7 (22)
>500	25.8 (23)
C. How many beds does your emergency department have?	
Beds	Percentage (n)
<8	0.0 (0)
5-10	0.0 (0)
11-15	12.4 (11)
16-20	10.1 (9)
>20	77.5 (69)
D. How many patient encounters does your emergency department have annually?	
Patient visits	Percentage (n)
<5,000	0.0 (0)
5,001-15,000	2.2 (2)
15,001-30,000	12.4 (11)
30,001-60,000	42.7 (38)
60,001-100,000	24.7 (22)
>100,000	18.0 (16)

(*www.surveymonkey.com*) encrypted with Secure Sockets Layer technology. The survey was designed so that no individual respondent could be identified from any submitted responses.

No comprehensive, accurate, and up-to-date listing of ED directors could be found, so each hospital in the 12 designated cities was contacted telephonically (a) to determine whether that hospital had a 24-hour-available ED with a physician director and (b) for each hospital meeting the inclusion criteria for the study, to request the name and, when available, the E-mail address of the physician director of the ED.

On February 1, 2010, an E-mail invitation was sent to each of the E-mail addresses obtained for the physician ED directors in the 220 hospitals meeting inclusion criteria for the study. Repeat invitations were sent to nonrespondents 2, 4, 6, and 8 weeks after the initial invitation. Because of incorrect contact information for many of the directors, additional contact attempts were made beyond 8 weeks, and the survey was officially closed on July 25, 2010.

Statistical elements of SurveyMonkey were used to analyze data, and descriptive statistics were used to present the data. No responses were traceable to individual participants.

Results

Despite repeated attempts, E-mail invitations to 46 of the physician ED directors were returned as undeliverable, and additional attempts to reach these directors were unsuccessful. Of the remaining 174 directors, eight (4.6 percent) declined to fill out the survey and 89 (51.1 percent) took the survey. All 89 respondents answered all of the initial demographic questions, and 85 proceeded to the nondemographic questions; 80 directors answered all 30 of the nondemographic questions.

Table 2 gives the demographics of the responding hospitals. New York City, with 29 respondents, represented 32.6 percent of the total. Nearly half of the responding hospitals had 101-300 beds, and hospitals with 301-500 beds and with more than 500 beds each represented about a quarter of the total. Three-quarters of EDs had more than 20 beds; none had 10 or fewer. EDs with between 30,000 and 60,000 patient encounters

per year represented 42.7 percent of the total, and 18 percent had more than 100,000 visits annually.

Table 3 presents the results for the five questions about planning and communication. All respondents reported that their hospitals had disaster plans; 65.9 percent (56/85) of these plans specifically addressed MCIs from anticholinesterases. More than half of the directors (50.6 percent [43/85]) were very familiar with the Hospital Incident Command System (HICS), and only 2.4 percent (2/85]) had never heard of it. Similarly, almost half of the respondents (47.1 percent [40/85]) reported being very familiar with specific roles assigned to ED personnel in HICS. Percentages of respondents with written agreements for cooperation in the event of MCIs ranged from as high as 76.5 percent (65/85) for those with agreements with emergency medical services (EMSs) to 11.8 percent (10/85) who reported having no written agreements at all. Slightly more than half of the responding directors (56.5 percent [48/85]) felt that in an actual MCI, communication between their EDs and other hospitals would work moderately or very well; 43.5 percent (37/85) felt that the effectiveness of such communications would be slight at best in such a disaster.

The responses to the five questions (questions 6-10) about decontamination, detection, and PPE are given in Table 4, which shows that 94.0 percent (79/84) of reporting EDs had decontamination facilities for chemically contaminated patients. The estimated rapidity of chemical decontamination for reporting facilities varied as follows: 13.1 percent (11/84) of respondents reported being able to decontaminate more than 50 patients per hour, whereas nearly one-third (32.1 percent [27/84]) estimated that their EDs would be able to handle fewer than 10 patients per hour. The response with the largest percentage (35.7 percent [30/84]) was 10-19 patients per hour. Only a quarter of respondents (21/84) reported ready availability of chemical detection equipment for use immediately outside their EDs; more than half (53.6 percent [45/84]) answered that they had no such equipment; and one-fifth (21.4 percent [18/84]) did not know. Most of the respondents (88.1 percent [74/84]) were confident that adequate PPE would be available for use of decontamination staff just outside their EDs, but only 14.3 percent (12/84) were very familiar with *OSHA Best Practices for Hospital-based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances*[39]; nearly a quarter (23.8 percent [20/84]) had never heard of this document.

Training and drills were addressed by questions 11-14 (Table 5). More than two-thirds (70.8 percent [58/82]) of those who took the survey had had at least 1 hour of formal didactic training concerning anticholinesterases within the last 3 years; 22.0 percent (18/82) of respondents had had such training within the past year. Slightly more than a quarter (26.8 percent [22/82]) had had anticholinesterase-related training more than 3 years previously. Only 18.3 percent (15/82) were very confident that their training had equipped them to respond to an imminent MCI involving these chemicals; another one-third (32.9 percent [27/82]) were moderately confident. Disaster drills that included anticholinesterases were far less frequently reported, with only 7.3 percent (6/82) reporting such a drill within the previous year and only 30.5 percent (25/82) answering that they had participated in this kind of a drill within the past 3 years. To the question that asked specifically about the frequency of these drills, 28.0 percent (23/82) answered that they had never taken part in such a drill; in response to the next question, which asked about the effects of the drills, 19.5 percent (16/82) reported never having participated in an anticholinesterase-related drill. Only 4.9 percent (4/82) of ED directors were very confident that their drill experiences had prepared them for a real MCI, and more than half (51.2 percent [42/82]) were either not confident at all or only slightly confident in the effectiveness of their drills.

Table 6 reports the results from the four-question section (questions 15-18) about capacity and staffing. Almost two-fifths (39.0 percent [32/82]) of respondents estimated that they would be able to triage between 20 and 50 incoming patients in an anticholinesterase-related MCI; at the extremes, 14.6 percent (12/82) felt incapable of triaging 10 or more per hour, whereas 11.0 percent (9/82) answered that they could triage more than 50 per hour. Rates for evaluating and treating such patients were lower: 24.4 percent (20/82) thought that they could not handle 10 or more patients an hour, and only 4.9 percent (4/82) felt confident that they could evaluate and treat more than

Table 3. Planning and communication (questions 1-5)	
Response	**Percentage (n)***
1. Does your hospital disaster/emergency medical plan specifically address mass casualty incidents from anticholinesterases?	
Yes	65.9 (56)
No	20.0 (17)
I don't know.	14.1 (12)
My hospital does not have a disaster/emergency medical plan.	0.0 (0)
Comments: Has plan, not yet drilled.	
2. How familiar are you with the Hospital Incident Command System (HICS)?	
I've never heard of it.	2.4 (2)
Slightly familiar	15.3 (13)
Moderately familiar	31.8 (27)
Very familiar	50.6 (43)
Comments: I am acting chief of ER and doing mostly patient care.	
3. How familiar are you with specific roles assigned to ED personnel in HICS?	
Not familiar at all	2.4 (2)
Slightly familiar	15.3 (13)
Moderately familiar	35.3 (30)
Very familiar	47.1 (40)
Comments: None.	
4. With which of the following in your area does your hospital have a written agreement for cooperation with respect to a mass casualty incident? (Please check all that apply.)	
EMS	76.5 (65)
Private ambulance services	36.5 (31)
Fire services	49.4 (42)
Police	41.2 (35)
Nearby hospitals	64.7 (55)
None of the above	11.8 (10)
Comments: Ten comments, mostly expressing doubt that written agreements exist.	
5. How well do you think that communication between your ED and other hospitals will work in a mass casualty incident involving anticholinesterases?	
Not at all	4.7 (4)
Slightly	38.8 (33)
Moderately well	41.2 (35)
Very well	15.3 (13)
Comments: Four comments, including "Given how rare these events are, I think there would be chaos with initial communications" and "By routine communications! Very poorly."	
*Because a few respondents skipped these questions, total number of recipients per question may be less than the number who took the survey.	

Table 4. Decontamination, detectors, and personal protective equipment (questions 6-10)	
Response	**Percentage (n)***
6. Does your ED have decontamination facilities for chemically contaminated patients?	
Yes	94.0 (79)
No	6.0 (5)
I don't know.	0.0 (0)
Comments: Ten comments, including "I have no idea—this is a guess," "This is for worried well and walking wounded. Critically injured patients may reduce this number," and "Like anything else, there will be a learning curve here."	
7. How rapidly can anticholinesterase-exposed patients arriving just outside your ED be decontaminated?	
<10 per hour	32.1 (27)
10-19 per hour	35.7 (30)
20-50 per hour	19.0 (16)
>50 per hour	13.1 (11)
8. Is functioning chemical detection equipment readily available for use immediately outside your ED?	
Yes	25.0 (21)
No	53.6 (45)
I don't know.	21.4 (18)
Comments: Three comments: "I believe it is available but not readily," "We have radiation detection equipment," and "fire department has this."	
9. Is adequate personal protective equipment (PPE) readily available for use by decontamination staff immediately outside your ED?	
Yes	88.1 (74)
No	3.6 (3)
I don't know.	8.3 (7)
Comment: "We have about 10-20 high-level suits."	
10. How familiar are you with OSHA Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances?	
I've never heard of it.	23.8 (20)
Slightly familiar	45.2 (38)
Moderately familiar	16.7 (14)
Very familiar	14.3 (12)
Comment: "The manager of the decon team is very familiar."	
*Because a few respondents skipped questions, total numbers of recipients per question may be less than the number who took the survey.	

Table 5. Training and drills (questions 11-14)	
Response	**Percentage (n)***
11. When was the last time that you had 1 hour or more of formal didactic training (eg, a course or a lecture) specifically involving anticholinesterases?	
Within the past 12 months	22.0 (18)
Within the past 1-3 years	48.8 (40)
More than 3 years ago	26.8 (22)
Never	1.2 (1)
I don't know.	1.2 (1)
Comments: Three comments: "I teach it to the EM residents," "More than 14 years ago while still in military," and "It was brief."	
12. How confident are you that your last formal training has equipped you to respond tomorrow to a mass casualty incident involving anticholinesterases?	
Not confident at all	11.0 (9)
Slightly confident	36.6 (30)
Moderately confident	32.9 (27)
Very confident	18.3 (15)
No formal ED training involving anticholinesterases.	1.2 (1)
Comment: "Mechanics not medicine that would be prob."	
13. When was the last time that you had a disaster drill specifically involving anticholinesterases?	
Within the past 12 months	7.3 (6)
Within the past 1-3 years	30.5 (25)
More than 3 years ago	18.3 (15)
Never	28.0 (23)
I don't know.	15.9 (13)
14. How confident are you that your last drill has prepared you to respond tomorrow to a mass casualty incident involving anticholinesterases?	
Not confident at all	17.1 (14)
Slightly confident	34.1 (28)
Moderately confident	24.4 (20)
Very confident	4.9 (4)
No participation in any ED drills involving anticholinesterases.	19.5 (16)
Comment: "We have-attrited [*sic*] many of those trained to do the decontamination."	
*Because a few respondents skipped these questions, total numbers of recipients per question may be less than the number who took the survey.	

Table 6. Capacity and staffing (questions 15-18)	
Response	**Percentage (n)***
15. How rapidly can your ED triage patients (including acutely exposed patients and patients worried that they might be exposed) from a mass casualty incident involving anticholinesterases?	
<10 per hour	14.6 (12)
10-19 per hour	28.0 (23)
20-50 per hour	39.0 (32)
>50 per hour	11.0 (9)
I don't know.	7.3 (6)
Comment: "Until the tags run out."	
16. How rapidly can your ED evaluate and treat anticholinesterase-exposed patients from a mass casualty incident?	
<10 per hour	24.4 (20)
10-19 per hour	36.6 (30)
20-50 per hour	24.4 (20)
>50 per hour	4.9 (4)
I don't know.	9.8 (8)
17. How rapidly can your ED manage apneic patients from a mass casualty incident involving anticholinesterases?	
<10 per hour	61.0 (50)
10-19 per hour	26.8 (22)
20-50 per hour	3.7 (3)
>50 per hour	2.4 (2)
I don't know.	6.1 (5)
18. How confident are you that additional staff will be available to you in the event of a mass casualty incident involving anticholinesterases?	
Not confident at all	15.9 (13)
Slightly confident	23.2 (19)
Moderately confident	30.5 (25)
Very confident	30.5 (25)
Comment: "Problem is timeliness."	

50 patients per hour. The rates for managing cholinesterase-poisoned patients who were apneic were even lower, with 61.0 percent (50/82) estimating that they could not handle 10 or more apneic patients per hour (interestingly, 2.4 percent [2/82] felt capable of managing more than 50 apneic patients per hour). Confidence of obtaining additional staff in an anticholinesterase-related MCI ranged from not confident at all (15.9 percent [13/82]) through slightly confident (23.2 percent [19/82]) to moderately confident (30.5 percent [25/82]) and very confident (also 30.5 percent [25/82]).

The largest number of questions, nine (questions 19-27), concerned antidotes to anticholinesterase compounds. Table 7 shows that nearly a quarter (23.2 percent [19/82]) of physician ED directors denied ever having heard of the Division of Strategic National Stockpile (DSNS), 30.5 percent (25/82) were slightly familiar with it, 22.0 percent (18/82) were moderately familiar, and 24.4 percent (20/82) were very familiar. Although just more than a quarter (25.6 percent [21/82]) were very familiar with the related CHEMPACK program, 37.8 percent (31/82) of respondents had never heard of CHEMPACK. Slightly more than two-fifths (42.7 percent [35/82]) of directors reported that CHEMPACK nerve agent antidotes were prepositioned in their hospitals; a similar percentage (43.9 percent [36/82]) could not say whether or not CHEMPACK antidotes were available to them, and 42.7 percent (35/82) of respondents were not sure how their EDs would use CHEMPACK/DSNS in an anticholinesterase-related MCI. Nearly one-tenth (8.5 percent [7/82]) planned to use such stockpiles as the primary source of antidotes for patients; 29.3 percent (24/82) contemplated using the stockpiles to replenish antidotes already available in hospital; and 18.3 percent (15/82) wanted to use CHEMPACK/DSNS both as the primary source of antidotes and also as a resupply. The single highest percentage response for each of the questions regarding the number of severely exposed patients able to be treated with antidotes already on hand in reporting hospitals was "I don't know"; the next more frequent response was the fewer-than-10-patients option. The benzodiazepine of choice for most ED directors in treating anticholinesterase-induced seizures was lorazepam (42.7 percent [35/82]), followed by "no preference" (28.0 percent [23/82]) and then diazepam (18.3 percent [15/82]). Midazolam came in a distant third at 8.5 percent (7/82).

The final three survey questions (questions 28-30; see Table 8) addressed the issue of information resources. Fewer than half of the ED directors (45.7 percent [37/81]) were able to rely on a board-certified medical toxicologist directly employed by or affiliated with their hospitals. Almost all respondents (95.1 percent [77/81]) reported access to a local poison control center, and 81.5 percent (66/81) considered the Internet a readily available information resource. The Internet-based and downloadable Radiation Event Medical Management (REMM) program, designed for nuclear and radiation MCIs, was unknown to almost two-fifths (39.5 percent [32/81]) of ED directors, although 37.0 percent (30/81) and 17.3 percent (14/81) were slightly and moderately familiar, respectively, with it; only 6.2 percent (5/81) considered themselves very familiar with this module. However, nearly half of the respondents (48.1 percent [39/81]) and 73.6 percent (39/53) of those familiar with REMM felt that a chemical counterpart of REMM would be moderately to very helpful in dealing with MCIs involving anticholinesterases.

Respondents were given the opportunity not only to provide comments on individual questions but also to leave comments on the survey as a whole. These general comments are given in Table 9.

Discussion

This survey illustrates several deficiencies in the preparedness of EDs in major US metropolitan areas to manage MCIs involving the release of anticholinesterase compounds (carbamate insecticides, OP insecticides, or nerve agents).

Several reports have underscored the importance of so-called all-hazard hospital disaster plans that are nevertheless based on specific hazard-vulnerability analysis (not addressed in this 30-question survey) and that can be adapted to specific threats such as chemical releases.[40-43] Previous surveys have shown that the development of written plans is one of the first administrative actions in preparing for a disaster, and all respondents in this survey reported the existence of disaster plans at their hospitals. This survey did not attempt to

Table 7. Antidotes (questions 19-27)	
Response	**Percentage (n)***
19. How familiar are you with the Division of Strategic National Stockpile (DSNS)?	
I've never heard of it.	23.2 (19)
Slightly familiar	30.5 (25)
Moderately familiar	22.0 (18)
Very familiar	24.4 (20)
20. How familiar are you with the CHEMPACK program?	
I've never heard of it.	37.8 (31)
Slightly familiar	20.76 (17)
Moderately familiar	15.9 (13)
Very familiar	25.6 (21)
21. Are CHEMPACK antidotes for nerve-agent casualties prepositioned in your hospital?	
Yes	42.7 (35)
No	13.4 (11)
I don't know.	43.9 (36)
Comments: Four comments: "I don't know quantity," "The watch commander for NYC OEM has a low threashold [*sic*] for releasing CHEMPACK to the surrounding hospitals if an event is suspected based on radio traffic monitoring. The first indication the hospital may have that an event may occur is the delivery of the CHEMPACK," "Not sure where," and "We have Mark 1 kits."	
22. How does your ED plan to use CHEMPACK/DSNS in a mass casualty incident involving anticholinesterases?	
As the primary source of antidotes for patients	8.5 (7)
As a resupply for antidotes already available in the hospital	29.3 (24)
Both as the primary source of antidotes and also as a resupply	18.3 (15)
My ED does not plan to use either in such an incident.	1.2 (1)
I don't know.	42.7 (35)
23. How many severely exposed OP-insecticide–exposed patients (ie, patients needing at least 6 mg of atropine each) could you treat in your emergency department before needing additional atropine either from CHEMPACK or from the DSNS?	
<10	28.0 (23)
10-19	20.7 (17)
20-50	9.8 (8)
>50	8.5 (7)
I don't know.	32.9 (27)

(continued)

Table 7. Antidotes (questions 19-27) (continued)	
Response	**Percentage (n)***
24. How many severely exposed nerve-agent-exposed patients (ie, patients needing at least 6 mg of atropine each) could you treat in your emergency department before needing additional atropine either from CHEMPACK or from the DSNS?	
<10	28.0 (23)
10-19	18.3 (15)
20-50	12.2 (10)
>50	8.5 (7)
I don't know.	32.9 (27)
25. How many severely anticholinesterase-exposed patients (ie, patients needing at least 1,800 mg of pralidoxime chloride each) could you treat in your emergency department before needing additional pralidoxime chloride either from CHEMPACK or from the DSNS?	
<10	36.6 (30)
10-19	15.9 (13)
20-50	7.3 (6)
>50	36.6 (30)
I don't know.	
26. How many severely anticholinesterase-exposed patients (ie, patients either seizing or at a high risk of seizing) could you treat in your emergency department before needing additional benzodiazepine supplies either from CHEMPACK or from the DSNS?	
<10	23.2 (19)
10-19	23.2 (19)
20-50	11.0 (9)
>50	13.4 (11)
I don't know.	29.3 (24)
27. As the director of your emergency department, which benzodiazepine would you prefer to use in a mass casualty incident involving anticholinesterases?	
Diazepam	18.3 (15)
Midazolam	8.5 (7)
Lorazepam	42.7 (35)
I have no preference.	28.0 (23)
I don't know.	2.4 (2)
*Because a few respondents skipped these questions, total numbers of recipients per question may be less than the number who took the survey.	

Table 8. Additional resources (questions 28-30)	
Response	**Percentage (n)***
28. What consultative resources are readily available to your emergency department in the event of a mass casualty incident involving anticholinesterases? (Please check all that apply.)	
A board-certified medical toxicologist for my hospital	45.7 (37)
A local poison control center	95.1 (77)
The Internet	81.5 (66)
Other resources	32.1 (26)
I do not anticipate using resources outside my ED.	2.5 (2)
Comments: Three comments: "Bio-terrorism regional network," "PharmD with special interest in Tox is 0.5 FTE employee," and "We employee a Director for Disaster Preparedness."	
29. How familiar are you with Radiation Event Medical Management (REMM) from the US Department of Health and Human Services and the National Library of Medicine?	
I've never heard of it.	39.5 (32)
Slightly familiar	37.0 (30)
Moderately familiar	17.3 (14)
Very familiar	6.2 (5)
30. How helpful would you find a chemical counterpart of REMM for mass casualty incidents involving anticholinesterases?	
Not helpful at all	2.5 (2)
Slightly helpful	14.8 (12)
Moderately helpful	29.6 (24)
Very helpful	18.5 (15)
I am not familiar with REMM.	34.6 (28)
*Because a few respondents skipped these questions, total numbers of recipients per question may be less than the number who took the survey.	

evaluate the adequacy of the existing plans. HICS (formerly called the Hospital Emergency Incident Command System)[44] is an adaptation for hospitals of the incident command system mandated by The Joint Commission; its importance is widely recognized.[45,46] It is not surprising that almost all ED directors had at least heard of HICS, although the finding that only about half were very conversant with it and that just over half were very familiar with specific roles assigned to ED personnel in HICS is disturbing. Similarly, although experiences with both simulated and actual MCIs have proven that communication, including communication involving written memoranda, is almost universally a weak link in a disaster,[47-50] the observation that more than one-third of respondents reported no written agreements with other hospitals is discouraging. The large spread in expectations about how well communications would actually work in a chemical MCI is difficult to explain.

Decontamination is one of the crucial components of immediate prehospital and ED care of a victim with ingestion or skin exposure to anticholinesterases.[16,51] Skin decontamination is particularly important not only to protect hospital facilities and healthcare workers[21,22,52] but also because any liquid still in contact with the skin of a casualty has the potential of being converted from an external to an internal dose. Moreover, chemical agents on the skin must be removed as soon as possible before significant skin penetration can occur, as compounds that have begun to penetrate the skin are not normally susceptible to surface decontamination.[53] The perception by 32.1 percent of ED directors that their EDs would not be able to decontaminate 10 or more patients per hour is thus particularly distressing. Related causes for concern from this survey are the observations that only a quarter of respondents reported readily available chemical detectors (vital in assuring that no liquid decontamination remains on the skin of victims) and that only 14.3 percent were very familiar with *OSHA Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances*,[39] a foundational report that sets out important guiding principles for decontamination of chemical casualties. Several recommendations[46,54,55] exist for improving the capability of EDs to decontaminate victims of chemical MCIs, and remediation of this deficiency should be pursued aggressively.

It is a given that all emergency physicians must receive adequate preparatory and continuing didactic education and must also learn and practice skills such as advanced cardiac life support in intensive simulations or drills. Such training and practice are reinforced by daily encounters with real patients in EDs. This kind of daily reinforcement is lacking for low-probability but high-impact events such as chemical MCIs, making the issues of training and drilling even more important in preparation for chemical disasters[56] despite the lack of a widespread standardized curriculum for training emergency medicine residents in disaster medicine[57] and the widespread perception that emergency-preparedness training is not a high priority in many areas.[58] The fact that 70.8 percent of respondents in this survey had had at least 1 hour of formal didactic training about anticholinesterases within the preceding 3 years is a step in the right direction, but the quality of the training can be surmised from the related finding that only 18.3 percent of ED directors thought that their training had equipped them to respond adequately to an imminent large-scale release of an anticholinesterase compound. Disaster drills that included anticholinesterases were even less frequently reported, and only 4.9 percent of respondents reported that their participation in drills had made them very confident of their ability to respond to a real MCI of this nature. Several plans for education and drilling exist[57,59-64] and include the organization of a trained and dedicated response team,[65] an intensive three-hour course,[66] the National Training Strategy,[58,67] and an integrated disaster medicine continuing education program[68]; the findings of this section of the current survey strongly argue for increased emphasis on adopting one or more of these proposals.

Rapid triage and treatment of patients after the release of large quantities of anticholinesterase compounds is complicated by the fact that EDs are likely to be flooded with individuals who think that they may have been exposed and who in fact may exhibit psychological effects mimicking those of anticholinesterase intoxication while also being delayed in their presentation of clinical signs and symptoms of actual poisoning.[69,70] Nearly one-sixth of respondents (14.6 percent) thought that their EDs could triage fewer than 10 patients per hour, although it is encouraging that 57.3 percent anticipated being able to triage 20 or more patients per hour. Capacity markedly decreased for the questions concerning the treatment of severely exposed patients, particularly apneic patients; however, this finding was expected.[71-73] Anticipations of receiving needed additional staff were relatively high in this survey. Innovative methods of increasing the rate of triage and treatment of chemical casualties have been reported[74-77] and should be investigated seriously in this regard. Augmenting the capability of managing ventilator-dependent anticholinesterase casualties has also been studied[78-80] and shown to be feasible.

The choice and availability of pharmaceuticals (atropine, 2-pralidoximine chloride, and benzodiazepines) is one of the most anxiety-producing aspects

of preparing for anticholinesterase mass casualties.[81] The DSNS was established to help replenish antidotes used by a hospital during an anticholinesterase MCI.[82] The realization that most such casualties would need treatment before 12-hour push packages from strategically positioned DSNS stockpile sites around the country would be likely to be delivered prompted the expansion of the national stockpile in 2003 to include the CHEMPACK program for prepositioning of initial stockpiles of antidotes directly at hospitals.[83-85] The finding that 23.2 percent of physician ED directors had not heard of DSNS and that 37.8 percent had not heard of CHEMPACK is thus alarming, as is the observation that nearly half of the directors were not sure how their EDs would use CHEMPACK/DSNS. It could be argued that this responsibility rests with hospital pharmacists, but in fact ED physicians need to be actively involved with hospital pharmacies in assessing hospital stockpiles of anticholinesterase antidotes and what would be needed in a mass casualty event. This survey demonstrates not only that many ED directors do not have an understanding of the roles that prepositioning and resupply of these antidotes would play in a chemical MCI but also that they are unable to estimate how many anticholinesterase casualties could be treated with antidotes on hand in their hospitals. The expressed preference of ED directors for benzodiazepines other than midazolam is interesting in view of recent evidence that in the setting of intramuscular administration, and probably via the intravenous route as well, midazolam may be superior to other benzodiazepines, particularly lorazepam (the most popular choice among respondents in this survey), in the prevention and management of OP-induced seizures.[86-91] The results of this section of the survey should be of immense interest to the DSNS and to other governmental agencies tasked with MCI antidotal recommendations for hospital EDs.

Knowing when to seek additional resources and where to go to find them is an important skill for all emergency physicians.[92] This ability to seek and find relevant information resources is paramount when EDs are flooded with patients with the possible diagnosis of anticholinesterase exposure.[93] It is thus encouraging that only 2.5 percent of respondents in this survey did not expect to use any resources outside their EDs in such an event. Access to a board-certified medical toxicologist would be ideal, but only 45.7 percent of respondents reported ready availability of a medical toxicologist directly employed by or affiliated with their hospitals. This finding by itself speaks to the need for more board-certified medical toxicologists in major medical centers. The most accessible reported resource (96.1 percent) was that of a local poison control center. Poison control centers have already been discussed as information resources for volunteer EMSs in cases of suspected chemical exposures[94]; this survey suggests that poison control centers also need to recognize the widespread dependence of EDs on poison center expertise in anticholinesterase MCIs and to ensure that communications between them and hospital EDs are not overwhelmed during such an incident. Telemedicine is another potential resource in a chemical emergency[95] but was not specifically addressed in this survey, although 32.1 percent of respondents expected to use resources either instead of or in addition to medical toxicologists, poison control centers, and the Internet. Online resources are likely to play a major role for clinicians in MCIs involving unfamiliar agents, just as they already serve an important function in other kinds of disasters.[96] One particularly useful resource for radiological or nuclear MCIs is REMM, an Internet-based but also downloadable and mobile information program from the National Library of Medicine (NLM) and the National Institutes of Health (NIH).[97,98] The observation that 39.5 percent of ED directors had never heard of REMM should be of interest to those at the NLM and NIH who have developed and who continue to revise and update this program and suggests that outreach for this excellent resource needs to continue. Nearly half of the respondents (48.1 percent)—and nearly two thirds (73.6 percent) of those familiar with REMM—felt that a chemical counterpart to REMM would be moderately to very useful in managing mass casualties from anticholinesterase exposure; this should provide added impetus to the ongoing development by NLM and NIH of the nascent program CHEMM (Chemical Hazard Emergency Medical Management).

An obvious limitation of this survey is the relatively low response rate. Of the 174 physician ED directors

Table 9. Additional comments
1. "We are a VA facility within blocks of major receiving center with EM facluty [*sic*] who are toxicologists."
2. "Please include me in the distribution of the results of your survey. Thanks."
3. "I am new to this position so I am not sure of the accuracy of all of my answers. I have reviewed our decontamination pplan [*sic*], availability of medications with pharmacy."
4. "Thank you for the survey, it really facilitates a drill we will be having in considering our upcoming needs."

who presumably received E-mail invitations, only 51.1 percent (89) began the survey and only 48.9 percent (84) proceeded beyond the introductory demographic questions. Only 4.6 percent (8) formally declined to take the survey; the reasons behind the silence of the remaining ED directors despite repeated and apparently received E-mail invitations are unclear. The survey was specifically created according to published guidelines for survey design,[99] and although more information from fewer participants might have resulted from the original 60-question instrument, it was decided to restrict the number of nondemographic questions to a total of 30. It was hypothesized that with the choice of an easily completed online survey and the clear explanation that only 30 questions would be required and that the total time required to fill out the survey should not exceed approximately 15 minutes, the response rate would be higher than for traditionally mailed surveys; this proved not to be the case. There was only a slight rise in unanswered questions near the end of the survey, suggesting that although a degree of "question fatigue" may have existed, it was not significant for those who actually took the survey. There is no way of knowing whether or to what extent nonrespondents may have differed from respondents in their perceptions of ED preparedness. However, this apparent limitation may also be a major finding of the study. For whatever reason, physician ED directors in major US cities may in general be so overwhelmed by daily activities or, alternatively, by misgivings about preparedness for chemical MCIs that they are unlikely to respond to a survey instrument of this type. There is evidence[100] that surveys, drill observation using a structured evaluation tool, and video analyses of team performance during drills may measure distinct aspects of disaster preparedness, and therefore future studies may need to emphasize a nonsurvey type of data collection. Of course, an inherent limitation of survey instruments is that perceptions, however firmly held, may not reflect the actual state of disaster preparedness, as after-action reports of disaster exercises and actual MCIs have demonstrated.

Another significant finding of this study was the observation that despite advances in technology since the 2002 Philadelphia survey[32] for which it proved impossible to find a reliable directory of ED physicians, such a directory remains elusive. The implications of this finding extend beyond the logistics of delivering a survey instrument: In a real MCI, it may be important to disseminate information quickly to ED directors. Without an available and reliable contact list of such directors, crucial data may not find its way to these directors in a timely fashion.

In 2002, Greenberg[32] proposed criteria (Table 10) for minimal preparedness for a hospital ED to evaluate and treat victims of biological or chemical agent release. Although those criteria could be expanded to address other issues such as triage and are not in every case applicable to the current study, 32.1 percent of the respondents in this survey would have failed criterion 2 (the ability to decontaminate at least 10 patients per hour) and 92.7 percent would have failed a modification of criterion 5 (participation within the preceding 12 months in a disaster drill specifically addressing anticholinesterases).

This study, the first survey in the literature with a focus on ED preparedness for MCIs involving anticholinesterases, demonstrates that physician ED directors in major US cities recognize several deficiencies in their ability to respond to such events. The survey findings point out specific deficiencies amenable to remediation and emphasize directions for further research and for policy actions to correct these deficiencies. The conclusion given by Farmer and Carlton in 2002 is just as valid today as it was then: "The potential impact of a

Table 10. Criteria for minimal preparedness for a hospital ED to evaluate and treat victims of biological of chemical-agent release[32]
1. At least one emergency physician on the staff who has completed formal training regarding biological and chemical weapons of mass destruction.
2. Ability to decontaminate at least 10 patients per hour.
3. Written policies addressing the evaluation and treatment of biological and chemical casualties.
4. Written cooperative agreements with local agencies addressing issues of biological and chemical terrorism.
5. Participation in a disaster exercise involving biological or chemical agents within the past 12 months.
6. Self-characterized adequate supplies of appropriate antidotes.

chemical attack with nerve agents could be devastating. As physicians, nurses, and allied health professionals, it is our professional and social responsibility to ensure that we have each taken the appropriate planning and medical knowledge steps to be prepared. Our best defense is proper education, training, and practice. We must address our medical response at every level, in every pertinent locale, and to every probable scenario, and we must have a well-rehearsed plan at the ready."[48] This caution applies especially to the EDs at the forefront of the medical response to such catastrophes.

Acknowledgments

The authors thank Colin O'Dea, MD, Dorian Schumann-Werb, MD, Allen Silfee, MD, and Melissa A. Madsen, RN, BSN, CNOR for their assistance with this study. Elements of this survey were presented in Denver, Colorado, on October 9, 2010, as a poster at the 2010 North American Congress of Clinical Toxicology (NACCT 2010). This study was approved as IRB Protocol #18478 (Emergency Department Preparedness for the Evaluation and Management of Mass Casualties from Anticholinesterase Compounds) by the Institutional Review Board (IRB #1) at the Drexel University College of Medicine on August 18, 2009. The study was entirely self-funded, and no grant support was used. The views expressed in this article are those of the authors and do not reflect the official policy of the Department of the Army, the Department of Defense, or the US Government.

James M. Madsen, MD, MPH, FCAP, FACOEM, COL, MC-FS, USA, Deputy Director, Chemical Casualty Care Division, US Army Medical Research Institute of Chemical Defense (USAMRICD), Aberdeen Proving Ground, Maryland.

Michael I. Greenberg, MD, MPH, Director, Fellowship in Medical Toxicology, Drexel University College of Medicine, Philadelphia, Pennsylvania.

References

1. Dara S, Ashton R, Farmer J, et al.: Worldwide disaster medical response: An historical perspective. *Crit Care Med.* 2005; 33(1): S2-S6.
2. Kade KA, Brinsfield KH, Serino RA, et al.: Emergency medical consequence planning and management for national special security events after September 11: Boston 2004. *Disaster Med Public Health Prep.* 2008; 2(3): 166-173.
3. Fry H: Using JCAHO standards as a starting point to prepare for an emergency. *Jt Comm Perspect.* 2001; 21(12): 4-5.
4. United States General Accouting Office: Hospital preparedness: Most urban hospitals have emergency plans but lack certain capacities for bioterrorism response. Report to Congressional Committees, United States General Accouting Office, Washington, DC, 2003.
5. Mann NC, MacKenzie E, Anderson C: Public health preparedness for mass-casualty events: A 2002 state-by-state assessment. *Prehosp Disaster Med.* 2004; 19(3): 245-255.
6. Born CT, Briggs SM, Ciraulo DL, et al.: Disasters and mass casualties. I. General principles of response and management. *J Am Acad Orthop Surg.* 2007; 15(7): 388-396.
7. Kaji AH, Waeckerle JF: Disaster medicine and the emergency medicine resident. *Ann Emerg Med.* 2003; 41(6): 865-870.
8. American College of Emergency Physicians: Disaster planning and response. *Ann Emerg Med.* 2008; 52(5): 581.
9. Perry RW, Lindell MK: Hospital planning for weapons of mass destruction incidents. *J Healthc Prot Manage.* 2007; 23(1): 27-39.
10. Alexander DA, Klein S: The challenge of preparation for a chemical, biological, radiological or nuclear terrorist attack. *J Postgrad Med.* 2006; 52(2): 126-131.
11. Burklow TR, Yu CE, Madsen JM: Industrial chemicals: Terrorist weapons of opportunity. *Pediatr Ann.* 2003; 32(4): 230-234.
12. Smith KJ, Skelton H: Chemical warfare agents: Their past and continuing threat and evolving therapies. Part I of II. *Skinmed.* 2003; 2(4): 215-221.
13. Evans G: Bioterrorism watch. Ease of access to deadly chemicals may be the greatest threat to hospital readiness. *Hosp Peer Rev.* 2002; 27(2): Suppl 1-2.
14. Parrish JS, Bradshaw DA: Toxic inhalational injury: Gas, vapor and vesicant exposure. *Respir Care Clin N Am.* 2004; 10(1): 43-58.
15. Baker D: Civilian exposure to toxic agents: Emergency medical response. *Prehosp Disaster Med.* 2004; 19(2): 174-178.
16. Schwenk M, Kluge S, Jaroni H: Toxicological aspects of preparedness and aftercare for chemical-incidents. *Toxicology.* 2005; 214(3): 232-248.
17. Agency for Toxic Substances Disease Registry: *Cholinesterase Inhibitors: Including Insecticides and Chemical Warfare Nerve Agents.* Atlanta, GA: Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, 2007: 153.

18. Mitchell A, Steffenson N, Hogan H, et al.: Acute organophosphate pesticide poisoning in children. *MCN Am J Matern Child Nurs*. 1995; 20(5): 261-268.
19. Leikin JB, Thomas RG, Walter FG, et al.: A review of nerve agent exposure for the critical care physician. *Crit Care Med*. 2002; 30(10): 2346-2354.
20. Cyr JC: Multivictim emergency care: A case study of organophosphate poisoning in sixty-seven children. *J Emerg Nurs*. 1988; 14(5): 277-279.
21. Geller RJ, Singleton KL, Tarantino ML, et al.: Nosocomial poisoning associated with emergency department treatment of organophosphate toxicity—Georgia, 2000. *J Toxicol Clin Toxicol*. 2001; 39(1): 109-111.
22. Geller RJ: Nosocomial poisoning: Organophosphate contamination of emergency room staff is real. *J Toxicol Clin Toxicol*. 2002; 40(2): 201-202.
23. Suzuki T, Morita H, Ono K, et al.: Sarin poisoning in Tokyo subway. *Lancet*. 1995; 345(8955): 980.
24. Ohbu S, Yamashina A, Takasu N, et al.: Sarin poisoning on Tokyo subway. *South Med J*. 1997; 90(6): 587-593.
25. Rotenberg JS, Newmark J: Nerve agent attacks on children: Diagnosis and management. *Pediatrics*. 2003; 112(3, Part 1): 648-658.
26. Endregard M, Pettersson Reif BA, Vik T, et al.: Consequence assessment of indoor dispersion of sarin—A hypothetical scenario. *J Hazard Mater*. 2010; 176(1-3): 381-388.
27. Burstein JL: Smoke and shadows: Measuring hospital disaster preparedness. *Ann Emerg Med*. 2008; 52(3): 230-231.
28. Keim ME, Pesik N, Twum-Danso NA: Lack of hospital preparedness for chemical terrorism in a major US city: 1996-2000. *Prehosp Disaster Med*. 2003; 18(3): 193-199.
29. Wetter DC, Daniell WE, Treser CD: Hospital preparedness for victims of chemical or biological terrorism. *Am J Public Health*. 2001; 91(5): 710-716.
30. Treat KN, Williams JM, Furbee PM, et al.: Hospital preparedness for weapons of mass destruction incidents: An initial assessment. *Ann Emerg Med*. 2001; 38(5): 562-565.
31. Niska RW, Burt CW: Bioterrorism and mass casualty preparedness in hospitals: United States, 2003. *Adv Data*. 2005;(364): 1-14.
32. Greenberg MI, Jurgens SM, Gracely EJ: Emergency department preparedness for the evaluation and treatment of victims of biological or chemical terrorist attack. *J Emerg Med*. 2002; 22(3): 273-278.
33. Connor DJ, White SM: Preparedness of London hospitals for a chemical weapons attack. *Lancet*. 2003; 361(9359): 786-787.
34. Wimbush S, Davies G, Lockey D: The presentation and management of victims of chemical and biological agents: A survey of knowledge of UK clinicians. *Resuscitation*. 2003; 58(3): 289-292.
35. Bennett RL: Chemical or biological terrorist attacks: An analysis of the preparedness of hospitals for managing victims affected by chemical or biological weapons of mass destruction. *Int J Environ Res Public Health* [Electronic Resource]. 2006; 3(1): 67-75.
36. Fenzl M, Jolliff H, Topinka M: Chemical exposure preparedness for emergency departments in a Midwestern city. *Am J Disaster Med*. 2008; 3(5): 273-281.
37. United States Census Bureau: Population estimates: Incorporated places and minor civil divisions. Available at *http://www.census.gov/popest/cities/SUB-EST2008.html*. Accessed July 28, 2010.
38. American Health Association. *AHA Guide 2009: Guide to U.S. Hospitals, Health Care Systems, Networks, Alliances, Health Organizations, Agencies, and Providers*. Chicago: AHA Press, 2008.
39. United States Occupational Health and Safety Administration: *OSHA Best Practices for Hospital-Based First Receivers of Victims from Mass Casualty Incidents Involving the Release of Hazardous Substances*. Washington, DC: Occupational Safety and Health Administration, 2007.
40. Maisel L: The crisis plan. Nearly every hospital has one; not all are ready to follow it. *Health Prog*. 1994; 75(8): 26-28.
41. Emergency preparedness for hospitals. An overview. *Health Devices*. 2001; 30(9-10): 365-369.
42. Collaboration and coordination in mass casualty disaster plans. *Healthc Hazard Manage Monit*. 2002; 15(5): 1-7.
43. Amaratunga CA, O'Sullivan TL, Phillips KP, et al.: Ready, aye ready? Support mechanisms for healthcare workers in emergency planning: A critical gap analysis of three hospital emergency plans. *Am J Disaster Med*. 2007; 2(4): 195-210.
44. Jacoby IJ: SARS and the Hospital Emergency Incident Command System (HEICS): Outbreak management as the mother of invention. *J Emerg Med*. 2005; 28(2): 225-226.
45. Burkle FM Jr, Hsu EB, Loehr M, et al.: Definition and functions of health unified command and emergency operations centers for large-scale bioevent disasters within the existing ICS. *Disaster Med Public Health Prep*. 2007; 1(2): 135-141.
46. Powers R: Organization of a hospital-based victim decontamination plan using the incident command structure. *Disaster Manag Response*. 2007; 5(4): 119-123.
47. Neil R: A call for help. Collaboration with community officials is key. *Mater Manag Health Care*. 2003; 12(9): 22-26.
48. Farmer JC, Carlton PK Jr: Who is 9-1-1 to the 9-1-1? *Crit Care Med*. 2002; 30(10): 2397-2398.
49. Farmer JC, Carlton PK Jr: Providing critical care during a disaster: The interface between disaster response agencies and hospitals. *Crit Care Med*. 2006; 34(3, Suppl): S56-S59.
50. Goldman M, Anderson T, Zehtabchi S, et al.: Testing hospital disaster communication plan has immense value. *Disaster Manag Response*. 2007; 5(2): 27.
51. Clarke SFJ, Chilcott RP, Wilson JC, et al.: Decontamination of multiple casualties who are chemically contaminated: A challenge for acute hospitals. *Prehosp Disaster Med*. 2008; 23(2): 175-181.
52. Horton DK, Burgess P, Rossiter S, et al.: Secondary contamination of emergency department personnel from *o*-chlorobenzylidene malononitrile exposure, 2002. *Ann Emerg Med*. 2005; 45(6): 655-658.
53. Hamilton MG, Hill I, Conley J, et al.: Clinical aspects of percutaneous poisoning by the chemical warfare agent VX: Effects of application site and decontamination. *Mil Med*. 2004; 169(11): 856-862.
54. Okumura T, Kondo H, Nagayama H, et al.: Simple triage and rapid decontamination of mass casualties with colored clothes pegs (STARDOM-CCP) system against chemical releases. *Prehosp Disaster Med*. 2007; 22(3): 233-236.
55. Phelps S, Doering G: The performance-level model of hospital decontamination preparedness. *Am J Disaster Med*. 2008; 3(3): 157-163.
56. Brosh T, Pilo R, Bichacho N, et al.: Effect of combinations of surface treatments and bonding agents on the bond strength of repaired composites. *J Prosthet Dent*. 1997; 77(2): 122-126.
57. Alexander A, Bandiera G, Mazurik L: A multiphase disaster training exercise for emergency medicine residents: Opportunity knocks. *Acad Emerg Med*. 2005; 12(5): 404-409.
58. Ablah E, Tinius AM, Konda K: The National Training Strategy for emergency preparedness: Collective lessons learned. *J Public Health Manage Pract*. 2009; 15(2, Suppl): S31-S35.
59. Armour SJ, Bastone P, Birnbaum M, et al.: Education issues in disaster medicine: Summary and action plan. *Prehosp Disaster Med*. 2001; 16(1): 46-49.
60. Seynaeve G, Archer F, Fisher J, et al.: International standards and guidelines on education and training for the multi-disciplinary health response to major events that threaten the health status of a community. *Prehosp Disaster Med*. 2004; 19(2): S17-S30.
61. Kyle RR, Via DK, Lowy RJ, et al.: A multidisciplinary approach to teach responses to weapons of mass destruction and terrorism

using combined simulation modalities. *J Clin Anesth*. 2004; 16(2): 152-158.
62. Behar S, Upperman JS, Ramirez M, et al.: Training medical staff for pediatric disaster victims: A comparison of different teaching methods. *Am J Disaster Med*. 2008; 3(4): 189-199.
63. Williams J, Nocera M, Casteel C: The effectiveness of disaster training for health care workers: A systematic review. *Ann Emerg Med*. 2008; 52(3): 211-222.
64. Collander B, Green B, Millo Y, et al.: Development of an "all-hazards" hospital disaster preparedness training course utilizing multi-modality teaching. *Prehosp Disaster Med*. 2008; 23(1): 63-67; discussion 68-69.
65. Bagatell S, Wiese J: The Elite Code Grey Team: A new model for residency preparedness and training in advance of a disaster. *Am J Med Sci*. 2008; 336(2): 174-178.
66. Scott LA: Disaster 101: A novel approach to health care students' disaster medicine and emergency preparedness training. *Disaster Med Public Health Prep*. 2009; 3(3): 139-140.
67. Ablah E: Emergency preparedness continuing education for community-based providers: The National Training Strategy. *J Public Health Manag Pract*. 2009; 15(2, Suppl): S1-S2.
68. Coule PL, Schwartz RB: The national disaster life support programs: A model for competency-based standardized and locally relevant training. *J Public Health Manag Pract*. 2009; 15(2, Suppl): S25-S30.
69. Leiba A, Goldberg A, Hourvitz A, et al.: Who should worry for the "worried well"? Analysis of mild casualties center drills in non-conventional scenarios. *Prehosp Disaster Med*. 2006; 21(6): 441-444.
70. Gabriel R, Ferrando L, Corton ES, et al.: Psychopathological consequences after a terrorist attack: An epidemiological study among victims, the general population, and police officers. *Eur Psychiatry*. 2007; 22(6): 339-346.
71. Branson RD, Rubinson L: Mechanical ventilation in mass casualty scenarios. *Respir Care*. 2008; 53(1): 38-39.
72. Muskat PC: Mass casualty chemical exposure and implications for respiratory failure. *Respir Care*. 2008; 53(1): 58-63; discussion 63-56.
73. Branson RD, Johannigman JA, Daugherty EL, et al.: Surge capacity mechanical ventilation. *Respir Care*. 2008; 53(1): 78-88; discussion 88-90.
74. Cieslak TJ, Rowe JR, Kortepeter MG, et al.: A field-expedient algorithmic approach to the clinical management of chemical and biological casualties. *Mil Med*. 2000; 165(9): 659-662.
75. Krauss B: Capnography as a rapid assessment and triage tool for chemical terrorism. *Pediatr Emerg Care*. 2005; 21(8): 493-497.
76. Krauss B, Heightman AJ: 15-Second triage tool. The use of capnography for the rapid assessment and triage of critically injured patients and victims of chemical terrorism. *J Emerg Med Serv*. 2006; 31(6): 60-62, 68.
77. Sam KG, Kondabolu K, Pati D, et al.: Poisoning severity score, APACHE II and GCS: Effective clinical indices for estimating severity and predicting outcome of acute organophosphorus and carbamate poisoning. *J Forensic Leg Med*. 2009; 16(5): 239-247.
78. Malatino EM: Strategic national stockpile: Overview and ventilator assets. *Respir Care*. 2008; 53(1): 91-95; discussion 95.
79. Wilgis J: Strategies for providing mechanical ventilation in a mass casualty incident: Distribution versus stockpiling. *Respir Care*. 2008; 53(1): 96-100; discussion 100-103.
80. Hanley ME, Bogdan GM: Mechanical ventilation in mass casualty scenarios. Augmenting staff: Project XTREME. *Respir Care*. 2008; 53(2): 176-188; discussion 189.
81. Mrvos R, Piposzar JD, Stein TM, et al.: Regional pharmaceutical preparation for biological and chemical terrorism. *J Toxicol Clin Toxicol*. 2003; 41(1): 17-21.
82. Esbitt D: The Strategic National Stockpile: Roles and responsibilities of health care professionals for receiving the stockpile assets. *Disaster Manag Response*. 2003; 1(3): 68-70.
83. Nolin K, Murphy C, Ahern JW, et al.: Chempack program: Role of the health-system pharmacist. *Am J Health Syst Pharm*. 2006; 63(22): 2188, 2190.
84. Hsu EB, Casani JA, Romanosky A, et al.: Critical assessment of statewide hospital pharmaceutical surge capabilities for chemical, biological, radiological, nuclear, and explosive incidents. *Prehosp Disaster Med*. 2007; 22(3): 214-218.
85. Courtney B, Easton J, Inglesby TV, et al.: Maximizing state and local medical countermeasure stockpile investments through the Shelf-Life Extension Program. *Biosecur Bioterror*. 2009; 7(1): 101-107.
86. Anderson DR, Harris LW, Chang FC, et al.: Antagonism of soman-induced convulsions by midazolam, diazepam and scopolamine. *Drug Chem Toxicol*. 1997; 20(3): 115-131.
87. Gilat E, Goldman M, Lahat E, et al.: Nasal midazolam as a novel anticonvulsive treatment against organophosphate-induced seizure activity in the guinea pig. *Arch Toxicol*. 2003; 77(3): 167-172.
88. Capacio BR, Byers CE, Merk KA, et al.: Pharmacokinetic studies of intramuscular midazolam in guinea pigs challenged with soman. *Drug Chem Toxicol*. 2004; 27(2): 95-110.
89. Gilat E, Kadar T, Levy A, et al.: Anticonvulsant treatment of sarin-induced seizures with nasal midazolam: An electrographic, behavioral, and histological study in freely moving rats. *Toxicol Appl Pharmacol*. 2005; 209(1): 74-85.
90. McDonough JH, Van Shura KE, LaMont JC, et al.: Comparison of the intramuscular, intranasal or sublingual routes of midazolam administration for the control of soman-induced seizures. *Basic Clin Pharmacol Toxicol*. 2009; 104(1): 27-34.
91. Skovira JW, McDonough JH, Shih T-M: Protection against sarin-induced seizures in rats by direct brain microinjection of scopolamine, midazolam or MK-801. *J Mol Neurosci*. 2010; 40(1-2): 56-62.
92. McDonnell SM, Perry HN, McLaughlin B, et al.: Information for disasters, information disasters, and disastrous information. *Prehosp Disaster Med*. 2007; 22(5): 406-413.
93. Hochstein C, Arnesen S, Goshorn J, et al.: Selected resources for emergency and disaster preparedness and response from the United States National Library of Medicine. *Med Ref Serv Q*. 2008; 27(1): 1-20.
94. Martin-Gill C, Baer AB, Holstege CP, et al.: Poison centers as information resources for volunteer EMS in a suspected chemical exposure. *J Emerg Med*. 2007; 32(4): 397-403.
95. Garshnek V, Burkle F: Applications of telemedicine and telecommunications to disaster medicine historical and future perspectives. *J Am Med Inform Assoc*. 1999; 6: 26-37.
96. Fordis M, Alexander J, McKellar J: Role of a database-driven web site in the immediate disaster response and recovery of an academic health center: The Katrina experience. *Acad Med*. 2007; 82(8): 769-772.
97. Bader JL, Nemhauser J, Chang F, et al.: Radiation event medical management (REMM): Website guidance for health care providers. *Prehosp Emerg Care*. 2008; 12(1): 1-11.
98. Coleman CN, Hrdina C, Bader JL, et al.: Medical response to a radiologic/nuclear event: Integrated plan from the Office of the Assistant Secretary for Preparedness and Response, Department of Health and Human Services. *Ann Emerg Med*. 2009; 53(2): 213-222.
99. Burns KEA, Duffett M, Kho ME, et al.: A guide for the design and conduct of self-administered surveys of clinicians. *CMAJ*. 2008; 179(3): 245-252.
100. Kaji AH, Langford V, Lewis RJ: Assessing hospital disaster preparedness: A comparison of an on-site survey, directly observed drill performance, and video analysis of teamwork. *Ann Emerg Med*. 2008; 52(3): 195-201.