Risk Factors for Adverse Health Effects Following Hazardous Materials Incidents

Jefferey L. Burgess MD, MPH
Dana F. Kovalchick, BA
James F. Lymp, PhD
Kelly B. Kyes, PhD
William O. Robertson, MD
Carl A. Brodkin, MD, MPH

To identify risk factors for persistent morbidity, we conducted a prospective study of individuals involved in hazardous materials incidents reported to the Washington Poison Center. Between December 1997 and October 1999, 202 subjects in 87 incidents were surveyed by telephone. Medical symptoms persisting for a minimum of 8 days after the incident were reported in 51 (25%) subjects, and 18 (9%) left work or school for more than 2 days because of the exposure. Medical intervention was reported in 46 (58%) of 79 subjects for whom medical records were available, and objective abnormalities were found in 57 (72%). Multiple logistic regression analysis indicated that subjects with dermal exposures, three or more alcoholic drinks per week, and previous use of psychiatric medications were more likely to report persistent symptoms. Divorced, widowed, or separated subjects, asthmatic subjects, and those having initial dermal symptoms were more likely to miss work or school for more than 2 days. Of patients evaluated at a health care facility, subjects with preexisting hypertension were more likely to receive medical treatment or have objective medical findings, whereas those with inhalation exposures and those decontaminated at the scene were less likely to be treated or have abnormalities. In our study, both incident and individual factors were predictive of adverse health effects, and these findings should be considered in planning the care of patients involved in hazardous materials incidents. (J Occup Environ Med. 2001;43:558–566)

From the Environmental & Occupational Health Unit, University of Arizona College of Public Health (Dr Burgess); Psychiatry and Behavioral Sciences (Ms Kovalchick), Department of Health Services (Dr Kyes), and the Occupational and Environmental Medicine Program (Dr Brodkin), University of Washington; the Washington Poison Center (Dr Robertson); and the Section of Biostatistics, Mayo Clinic (Dr Lymp).

Address correspondence to: Dr Jefferey L. Burgess, Environmental & Occupational Health, University of Arizona, 1435 N. Fremont, Box 210468, Tucson, AZ 85719-4197; e-mail jburgess@u.arizona.edu.

Hazardous materials can be broadly defined as chemicals, substances, materials, or waste that may pose an unreasonable risk to life, health, safety, property, or the environment. Hazardous materials incidents involve uncontrolled releases of these substances. Common examples include spills, explosions, and fires. These incidents are relatively frequent, particularly in areas with high population densities, and range in size from single-victim events to community disasters.[1] A national database reported 5531 hazardous materials events in 13 states in 1997, resulting in 28 deaths, transportation of 1261 individuals to a health care facility, and medical admission of 119 victims.[2]

At present, the majority of individuals exposed to hazardous materials incidents are transported to a health care facility for evaluation.[3] Many of these individuals have limited chemical exposure but are transported because of symptoms, lack of familiarity with hazardous chemicals, and medicolegal considerations. This process is expensive, and it is believed that many of these exposure victims could be safely evaluated and released from the scene of the event without additional medical care. First responders, such as firefighters and paramedics, are required to evaluate and treat individuals potentially exposed to hazardous materials. Although general guidelines are available,[4–6] there are currently no evidence-based criteria to assist first responders in making prehospital treatment decisions for individuals exposed to hazardous materials,

particularly for those without objective evidence of injury.

Because of their diversity, hazardous materials have a broad range of toxicity and a variable potential to cause injury. Although deaths have been reported after exposure,[2,7–9] the majority of incidents do not appear to result in significant injury.[3] Limited information is available on morbidity following hazardous materials exposure, and no published information could be found on the persistence of symptoms other than those following large-scale incidents, which account for only a small fraction of all incidents. The purpose of this study was to evaluate (1) adverse health effects following hazardous materials incidents, and (2) potential risk factors that could be used to identify individuals more likely to experience persistent morbidity. Such information could assist first responders in making prehospital treatment and transport decisions.

Methods

All hazardous materials incidents occurring in Washington State in which a first responder (firefighter, police, hazardous materials team member, or paramedic) responded to the scene of the incident were eligible for inclusion in the study. The incident must have been reported to the Washington Poison Center (WPC) within 24 hours of the exposure start time. Incidents were identified when first responders, health care practitioners, or citizens called the WPC to request information, as described in previous studies.[3,10] The study was approved by the University of Washington Human Subjects Division, Application #28–0457-C.

If the initial call to the WPC was received from a first responder, on-scene information was collected at that time. If the initial call was received from a health care facility or citizen, the WPC immediately identified and contacted the responding fire department to collect on-scene information. Information collected in the initial on-scene report included incident date, incident location, chemicals released, number of exposed individuals, telephone contact numbers, and whether transport to a health care facility occurred. Chemicals were grouped into the following categories for analysis: carbon monoxide; hydrocarbons (eg, natural gas, toluene, freon); irritants (eg, ammonia, pepper spray, chlorine, hydrochloric acid, sulfuric acid,); mixtures; pesticides; others; and unknown.

Telephone contact numbers for each subject were collected from the incident scene when available. If necessary, the WPC called health care facilities, fire departments, and places of employment to obtain those numbers. Potential subjects were contacted by telephone and surveyed 8 to 40 days after the incident by specially trained WPC staff or the study coordinator. Multiple telephone calls were made until contact with a person or recording device occurred. A maximum of three messages were left on telephone answering machines, voice mail, or with a person. Individuals not returning phone calls within 30 days after the incident were classified as unable to contact. Subjects reached by telephone and declining participation in the study were classified as refusals. Survey questions included information on the exposure, medical treatment since exposure, physiological and psychological symptoms since exposure, past medical history, habits (smoking/drinking), and employment and/or educational history. All survey information was entered into a database, and a sample (54%) of the surveys was manually verified, with an error rate of less than 0.1%.

For survey information, two outcome variables were chosen for analysis: the presence of at least one physiological symptom at the time of the telephone survey (coded as "persistent symptoms") and a time loss of greater than 2 days from work or school since the exposure (coded as "time loss"). Physiological symptoms were organized in five categories containing 19 symptoms: (1) mucous membrane (sore or dry throat, metallic taste in mouth, stuffy or runny nose, and itchy or irritated eyes); (2) pulmonary/cardiovascular (chest or lung irritation, cough, wheezing, sputum or phlegm production, shortness of breath at rest, shortness of breath while walking, shortness of breath while running, and chest pain); (3) dermal (dermatitis, eczema, or other skin rash); (4) neurological (headache, fatigue, dizziness or lightheadedness, and poor memory or concentration); and (5) gastrointestinal (abdominal pains and nausea or vomiting). Acute symptoms were defined as having onset within 60 minutes of exposure.

Each subject who was evaluated at a health care facility was sent up to three letters requesting permission to review medical records since the date of the exposure. If the subject did not respond after two letters, he or she was contacted by telephone. If the subject was under 18 years old, the subject and/or an adult (parent or guardian) was asked to sign a medical records release form. A data collection form was used to record medical treatment and outcome information. The form covered general victim information, on-scene and hospital treatment, and objective medical findings. All medical records were reviewed independently by at least two of the authors. Differences were discussed among the reviewers, and outcomes were decided by consensus.

Medical records were analyzed using two criteria: treatment provided at a health care facility, and objective medical abnormalities during the health care facility visit. Medical treatment in the hospital was defined as at least one of the following: intravenous fluids, oxygen, medication, or other (wounds dressed, bag for breathing, transfer to burn unit, or transfer to hyperbaric chamber). Objective medical findings were defined as at least one abnormal vital sign (blood pressure, pulse, respiration, and temperature); physical ex-

amination finding (altered level of consciousness, head/eye/ears/nose/throat abnormalities, heart, pulmonary, abdomen, neurological, dermal burns, and trauma); or laboratory/diagnostic test (spirometry, oximetry, arterial blood gas, carboxyhemoglobin, methemoglobin, x-ray, urine, blood, or other). For vital signs, two categories (abnormal and significantly abnormal) were defined. Abnormal physical examination, radiograph, and diagnostic testing results were noted and coded as either related or unrelated to the exposure on the basis of the clinical review of at least two of the authors.

Logistic regression models[11] were created for the following outcome variables: persistent symptoms, time loss, at least one abnormal finding or treatment, and at least one significant abnormal finding or treatment. In all models, the method of generalized estimating equations was used to account for the correlation between victims from the same event.[12] An exchangeable correlation matrix was used within events. The outcome variables of persistent symptoms and time loss were analyzed for all data. The outcome variables treatment and at least one abnormal finding, and treatment and at least one significant abnormal finding, were analyzed for subjects with medical records available for review but were restricted to cases without eye injuries (requiring eye decontamination in field or during initial hospital visit), trauma, dermal burns, prehospital loss of consciousness, prehospital intubation, and patients given other medical treatment in the field. This restriction was applied to focus on exposures with an indeterminate need for health care facility evaluation or treatment.

Each variable was initially entered into regression models separately for bivariate comparison. A multiple regression model was then constructed by starting with each variable that was a significant predictor at the $P < 0.10$ level in the bivariate models. Variables were then added and removed according to whether the variable was a significant predictor at the $P < 0.10$ level after adjusting for the other variables in the model.

The validity of the initial on-scene incident information was determined by recontacting the first-responder agency at least 1 month after the initial call. The purpose of the callback was to verify the incident date, incident time, responder unit/name, location, chemical name, chemical amount, combustion, enclosed space, event type (fixed site or during transport), and number of human victims. The person verifying the information either had been at the scene during the incident or had an incident report for reference. The first available on-scene form was compared with the final report. Initial and final on-scene variables were coded as same, different, or unknown. The chemical categories used in the regression analyses were based on the verified information contained in the final report.

Results

Over a 21-month period, 87 hazardous materials incidents in Washington State that fit our study criteria were reported to the WPC. The most common chemicals released are listed in Table 1. Thirty-five incidents (40%) were called into the poison center within an hour of the exposure time. Of the estimated 575 total individuals potentially exposed, telephone contact information was collected for 339 (59%). Of these, 93 (27%) refused and 44 (13%) were unable to be contacted. Surveys were completed for 202 subjects (60%) with contact information. Children (<18 years of age) represented 16% of participants, 4% of refusals, and 7% of those unable to be contacted. Female participants represented 55% of the study group, 48% of refusals, and 52% of those unable to be contacted. All participants were surveyed 8 to 40 days after the incident, with a mean and median of 19 days.

Acute and persistent symptoms grouped by organ system are illustrated in Fig. 1. The most common acute symptoms included headache (40%), cough (33%), itchy or irritated eyes (32%), sore or dry throat (32%), chest or lung irritation (26%), dizziness or lightheadedness (25%), and nausea or vomiting (20%). The most common persistent symptoms included fatigue (10%), sputum or phlegm production (8%), sore or dry throat (8%), stuffy or runny nose (8%), and cough (8%). Eighteen (9%) subjects reported time loss from work or school for greater than 2 days. Forty-two (21%) subjects reported chemical sensitivity before the incident, defined by an affirmative response to the question "Compared to other people, do you consider yourself allergic or unusually sensitive to everyday chemicals like those in household cleaning products, paints, perfumes, detergents, insect sprays, and things like that?" Two subjects first noticed chemical

TABLE 1
Common Chemicals Released in Hazardous Materials Incidents Reported to the Washington Poison Center

Chemical*	Incidents	Exposed Individuals†
Carbon monoxide	6	12
Pepper spray	5	10
Ammonia	4	8
Natural gas	4	11
Chlorine	3	10
Sulfuric acid	3	8
Hydrochloric acid	3	6
Mercury	3	6

* Chemicals released in a minimum of three incidents.
† Individuals limited to subjects completing surveys.

TABLE 2
Medical Treatment and Abnormalities in Subjects Seen at a Health Care Facility

	Prehospital	Initial Visit	Follow-Up Visit
Treatment			
Decontamination	15	13	
Medications	6	33	12
Oxygen	8	18	1
Intravenous	5	3	1
Other	2	6	

	Initial Visit		Follow-Up Visit	
	Related	Unrelated	Related	Unrelated
Abnormality				
Blood pressure*	25 (9)	2	3 (2)	
Pulse*	12 (5)			
Respiration*	13 (13)	1	1 (1)	
Temperature*	21 (0)		3 (0)	
Mental status	1			
Head, eyes, ears, nose, throat	15	2	6	1
Pulmonary	4	1	5	
Neurological			1	
Dermal/burns	8	1	5	
Trauma	2			
Oximetry†	1	1		
Arterial blood gas‡	3			
X-ray	7	1		2
Blood	5		3	1
Spirometry§	3		2	
Other	3			

* For vital signs, numbers of significant abnormalities are listed in parentheses. Abnormal blood pressure is ≥140/90 (significant ≥160/100); abnormal pulse is >100 or <60 (significant ≥110 or ≤50); abnormal respiration is >20 for adults, >22 for children (significant >25 for adults, >27.5 for children); abnormal temperature is >98.5°F (significant >100.5°F).

† Abnormal arterial oxygen percent saturation is <94%.

‡ Abnormal arterial blood gas included two pH (nL 7.35 to 7.45), two partial pressure of carbon dioxide (nL 33 to 48 mm Hg), and three bicarbonate to (nL 24 to 31 mm Hg) measurements.

§ Abnormal spirometry includes forced vital capacity or forced expiratory volume in one second less than 80% of predicted.

sensitivity after the incident. Of the subjects with preexisting chemical sensitivity, 4 reported increased sensitivity after the incident, 32 described no change, and 6 were unsure.

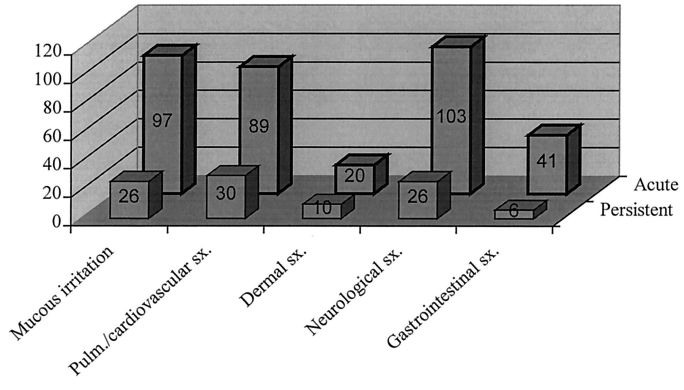

Fig. 1. Acute (onset within 60 minutes) and persistent (≥8 days) physiological symptoms following hazardous materials incidents.

One hundred nineteen subjects (59%) were transported to a health care facility. Three additional subjects were seen at a health care facility but were not transported directly from the incident scene. Medical records were received and reviewed for 79 (65%) of the 122 subjects seen at a health care facility (Table 2). Of the 79 subjects, 27 were also seen for a follow-up appointment. Forty-one subjects (52%) were male and 38 (48%) were female. Their mean age was 37.2 years (range, 9 to 79 years). Seventy-four (94%) were discharged, 3 (4%) were admitted, and 2 (3%) were transferred to another health care facility. For initial visits, 69 (87%) took place in an emergency department, 9 (11%) in a doctor's office or clinic, and 1 (1%) in urgent care. For follow-up visits, 4 (5%) took place in an emergency department, 21 (27%) in a doctor's office or clinic, and 2 (3%) in other locations. The interval between exposure and follow-up examination averaged 13 days with a median of 8.5 days.

Of the 79 subjects from whom medical records were obtained, 24 (30%) were treated in the prehospital setting, 46 (58%) received treatment at their initial visit, and 10 (13%) were treated during a follow-up visit. Included as a subset of medication, breathing treatments were given to three subjects during prehospital care, four subjects during initial visits, and three subjects during follow-up visits. Forty-two (53%) subjects had objective abnormal medical findings on initial visit and 17 (22%) on follow-up visit. Head, eyes, ears, nose, and throat abnormalities included predominantly injection or irritation of the conjunctiva and/or oropharynx and, to a lesser extent, corneal involvement, visual acuity changes, and one case of bloody nasal discharge. Pulmonary abnormalities included wheezing, rales and rhonchi, and one episode of hemoptysis; neurological findings included one case of tremor/hyperirritability. Chest radiograph abnormalities included atelectasis, peribronchial thick-

TABLE 3
Logistic Regression Analysis of Prehospital Subject and Event Risk Factors for at Least One Persistent Symptom

Variable/Value	Total	Persistent Symptoms	OR	95% CI*	Adj OR	95% CI*†
Dermal exposure						
Yes	32	13	2.35	0.86–6.38	*3.75*	*1.47–9.59*
No	170	38	1.00		1.00	
Drinks/week						
≥3	36	13	2.13	0.86–5.08	*3.16*	*1.13–8.80*
1–2	37	12	1.81	0.76–4.32	2.00	(0.76–5.28)
0	127	26	1.00		1.00	
Psychiatric medications‡						
Yes	34	12	1.93	0.89–4.20	*2.68*	*1.15–6.28*
No	163	38	1.00		1.00	
Significance explained§						
Yes	58	11	1.55	0.81–2.97	2.09	(0.91–4.84)
No	139	38	1.00		1.00	

* OR, Odds ratio; CI, confidence interval. Adjusted for correlation using generalized estimating equations.
† Adjusted for other variables in the model.
‡ Previous use of psychiatric medications.
§ Significance of exposure explained in the prehospital setting.

ening, and possible infiltrates. Abnormal hematological findings included abnormal hepatic aminotransaminases, electrolytes, and blood cell counts. Thirty-two subjects (41%) were found to have significantly abnormal objective medical findings on initial visit and 17 (22%) on follow-up visit. On physical examination, no cardiac or abdominal abnormalities were discovered. No abnormalities on urinalysis were revealed. On arterial blood gas and cooximetry analysis, no abnormalities of partial pressure of oxygen (normal, 70 to 90 mm Hg), carboxyhemoglobin, or methemoglobin were found.

For bivariate analysis with the outcome variable persistent symptoms, only one variable, transport to a health care facility, was a statistically significant predictor (odds ratio [OR], 3.28; 95% confidence interval [CI], 1.48 to 7.27). For multiple regression analysis (Table 3), dermal exposure, three or more drinks per week, and previous use of psychiatric medications were associated with an increased risk of persistent symptoms. When transport to a health care facility was included in the model, transported patients were more likely to have persistent symptoms (OR, 4.53; 95% CI, 1.73 to 11.9), and dermal exposure (OR, 4.08; 95% CI, 1.39 to 11.9), weekly alcohol intake ≥3 drinks/week (OR, 3.45; 95% CI, 1.21 to 9.83), and previous use of psychiatric medications (OR, 4.03; 95% CI, 1.63 to 9.92) remained statistically significant. In addition, subjects with acute gastrointestinal symptoms (OR, 0.39; 95% CI, 0.17 to 0.87) and carbon monoxide exposures (OR, 0.15; 95% CI, 0.03 to 0.94) had a decreased risk of persistent symptoms.

For the outcome variable time loss, transport to a health care facility (OR, 3.77; 95% CI, 1.07 to 13.3) was again a statistically significant predictor of increased risk in a bivariate regression model. Three or more drinks per week (OR, 3.17; 95% CI, 1.02 to 9.88) and eye irritation (OR, 2.97; 95% CI, 1.13 to 7.82) were associated with an increased risk, and indoor exposure (OR, 0.27; 95% CI, 0.09 to 0.81) was associated with a reduced risk of time loss in bivariate but not multiple regression analysis. In multiple regression analysis (Table 4), asthmatics; divorced, widowed or separated subjects; and those with acute dermal symptoms were at increased risk of time loss. The numbers of acute symptoms and alcoholic drinks per week were colinear with other variables and were not included in the final model. When transport to a health care facility was included in the model, exposure at work (OR, 0.12; 95% CI, 0.02 to 0.70); being divorced, widowed or separated (OR, 20.4; 95% CI, 1.55 to 268); alcohol use (1 to 2 drinks/week: OR, 29.2; 95% CI, 6.02 to 142; ≥3 drinks/week: OR, 12.0; 95% CI, 2.85 to 50.9); and present smoking (OR, 0.22; 95% CI, 0.06 to 0.78) were statistically significant, whereas asthma and acute dermal symptoms lost statistical significance.

Of the 79 patients evaluated in a health care facility for whom medical records were obtained, 17 (22%) had conditions or treatments that, in our opinion, required transport to a health care facility, including dermal burns, trauma, prehospital loss of consciousness, eye irrigation in field or hospital, intubation, and prehospital medication. For the remaining 62 patients (78%), exposure at work (OR, 4.98; 95% CI, 1.27 to 19.6) was a statistically significant predictor of an increased risk for medical treatment or at least one abnormal finding in a bivariate regression model, whereas carbon monoxide exposure (OR, 0.14; 95% CI, 0.03 to 0.65) was a predictor of reduced risk. In multiple regression analysis (Table 5), subjects with preexisting hypertension were at increased risk for medical treatment or at least one abnormal finding, whereas subjects decontaminated at the scene and subjects with inhalation exposures were at reduced risk.

For bivariate analysis of the outcome variable medical treatment or at least one significant abnormal finding, having acute pulmonary/cardiovascular symptoms was a statistically significant predictor of increased risk, whereas prehospital decontamination was associated with decreased risk. Results for multiple logistic regression analysis (Table 6) demonstrated an increased risk associated with preexisting hypertension, chest irritation,

TABLE 4
Logistic Regression Analysis of Prehospital Subject and Event Risk Factors for More Than 2 Days Missed From Work or School

Variable/Value	Total	Time Loss	OR	95% CI*	Adjusted OR	95% CI*†
Asthma						
Yes	28	7	*4.51*	*1.85–11.0*	*4.92*	*1.29–18.7*
No	169	11	1.00		1.00	
Exposure at work						
Yes	144	3	*0.19*	*0.05–0.70*	0.29	0.06–1.26
No	19	15	1.00		1.00	
Marital status						
Previous	22	4	*5.15*	1.56–16.9	*8.36*	*1.40–50.1*
Never	78	10	*3.02*	*1.11–8.24*	2.34	0.67–8.13
Married	95	4	1.00		1.00	
Acute dermal symptoms						
Yes	20	6	*5.54*	*1.78–17.3*	*6.77*	*1.34–34.2*
No	177	12	1.00		1.00	
Present smoker						
Yes	46	3	0.58	0.16–2.14	0.33	0.11–1.01
No	151	15	1.00		1.00	
Irritant exposure						
Yes	68	9	2.09	0.64–6.87	4.35	0.95–19.8
No	129	9	1.00	1.00		
Education						
≤12	46	12	2.43	0.88–6.74	2.94	0.87–9.96
>12	108	6	1.00		1.00	

* OR, odds ratio; CI, confidence interval. Adjusted for correlation using generalized estimating equations.
† Adjusted for other variables in the model.

and exposures of 11 to 60 minutes duration (compared with exposures of 0 to 10 minutes duration). There was a decreased risk associated with exposure to chemical mixtures.

Verification of the initial on-scene information was possible in 72 (83%) of the 87 incidents. The chemical type was in agreement in 60 (83%) of incidents, different in 8 (11%), and remained unknown in 4 (6%). In two incidents, additional chemicals were identified on follow-up, and one chemical originally unknown was identified. The chemical quantity was in agreement in 7 (10%) incidents, different in 13 (18%), and either remained unknown or was identified at follow-up in 52 (72%). Presence or absence of combustion was in agreement in 41 (57%) incidents, different in 1 (1%), and remained unknown in 30 (42%). Exposure within a confined space was in agreement in 34 (47%) incidents, different in 2 (3%), and remained unknown in 36 (50%).

A set of transport exclusion criteria developed on the basis of factors previously considered in our management of chemical incidents[10] was tested. These included not transporting subjects with any of the following to a health care facility: (1) carbon monoxide exposures with no acute symptoms, (2) hydrocarbon exposures with no CNS or mucous membrane symptoms, and (3) irritant exposures with no mucous membrane or pulmonary/cardiovascular symptoms. Using these criteria, 37 subjects would have been excluded from transport, 5 (14%) of whom had persistent symptoms. One hundred sixty-five subjects would have been transported, 46 (28%) of whom had persistent symptoms. These criteria had a sensitivity of 22%, a specificity of 90%, and an accuracy of 39% in determining exposed individuals who would not develop persistent symptoms. In this study, first-responder decisions not to transport had a sensitivity of 48%, a specificity of 78%, and an accuracy of 56% in determining exposed individuals who would not develop persistent symptoms.

Discussion

Although hazardous materials incidents can have severe health consequences,[7–9] our study found persis-

TABLE 5
Logistic Regression Analysis of Prehospital Subject and Event Risk Factors for Medical Treatment in a Health Care Facility or at Least One Abnormal Finding

Variable/Value	Total	Rx/ Abnormalities	OR	95% CI*	Adj OR	95% CI*†
Chest irritation						
Yes	18	16	4.39	0.8–21.2	7.39	0.76–71.7
No	44	29	1.00		1.00	
Decontamination						
Yes	12	7	0.44	0.16–1.24	*0.14*	*0.03–0.69*
No	50	38	1.00		1.00	
Hypertension						
Yes	14	13	6.50	0.74–57.0	*10.6*	*1.82–61.3*
No	48	32	1.00		1.00	
Inhalation exposure						
Yes	59	43	1.35	0.31–5.89	*0.17*	*0.04–0.78*
No	3	2	1.00		1.00	
Other/unknown chemical						
Yes	15	12	1.71	0.58–5.02	3.49	0.89–13.6
No	47	33	1.00		1.00	

* OR, odds ratio; CI, confidence interval. Adjusted for correlation using generalized estimating equations.
† Adjusted for other variables in the model.

TABLE 6.
Logistic Regression Analysis of Prehospital Subject and Event Risk Factors for Medical Treatment in a Health Care Facility or at Least One Significant Abnormal Finding

Variable/Value	Total	Rx/Abnormalities	OR	95% CI*	Adjusted OR	95% CI*†
Decontamination						
Yes	12	4	*0.31*	*0.10–0.96*	0.17	0.02–1.16
No	50	32	1.00		1.00	
Chest irritation						
Yes	18	15	*5.98*	*1.73–20.6*	*10.5*	*1.19–93.5*
No	44	21	1.00		1.00	
Hypertension						
Yes	14	11	3.19	0.78–13.1	*7.38*	*2.26–24.0*
No	48	25	1.00		1.00	
Minutes exposed						
>60	12	7	1.15	0.23–5.75	1.05	0.15–7.54
11–60	20	14	2.60	0.86–7.93	*5.27*	*1.08–25.7*
≤10	25	12	1.00		1.00	
Chemical						
Hydrocarbon	12	6	0.42	0.06–2.75	0.16	0.02–1.20
Mixture	5	2	0.36	0.05–2.41	*0.12*	*0.03–0.52*
Other	45	28	1.00		1.00	

* OR, odds ratio; CI, confidence interval. Adjusted for correlation using generalized estimating equations.
† Adjusted for other variables in the model.

tent symptoms and/or time loss in a minority of subjects. A majority of subjects transported to a health care facility received medical treatment or had objective abnormalities on physical examination or laboratory testing. However, most of these abnormalities were relatively minor. The relatively low occurrence of significant persistent morbidity supports the premise that fewer patients could be transported to a health care facility without compromising the provision of necessary care.[3]

Risk factors for adverse health effects varied greatly by outcome variable. Although a combination of incident and subject factors were statistically significant predictors, none was common to both the persistent symptoms and time loss multiple regression models. Including the variable transport to a health care facility in the model changed some of the other predictor variables. Modeling without transport addressed the question of which on-scene variables were associated with adverse outcomes. Inclusion of transport permitted the evaluation of the effects of this major treatment variable on other predictor variables.

Other data from Washington State indicate that first responders make treatment decisions based in part on patient symptoms, and that patients with headache and dizziness/other CNS symptoms are more likely to be transported to a health care facility.[13] The present study did not find that these symptoms, when experienced within 60 minutes of exposure, placed subjects at higher risk of adverse outcomes. The only patient symptoms found to be significant risk factors in multiple regression modeling were acute dermal symptoms (associated with an increased risk of time loss) and acute chest irritation (associated with an increased risk of medical treatment or significant abnormal objective findings). When transport to a health care facility was included, acute gastrointestinal symptoms were associated with a reduced risk of persistent symptoms. The significance of gastrointestinal symptoms is unclear but may represent psychological and physiological manifestations to exposure.[14–16] No association of adverse outcome with age was noted, although the small number of seniors (over 65 years of age) made it difficult to evaluate them separately, and the limited number of young children made it difficult to analyze them separately from older children.

The increased risk for persistent symptoms associated with transport of subjects to a health care facility, and the nonsignificant but elevated risk associated with transport in the time loss model, suggest that first responders are making appropriate transport decisions. However, their decisions have relatively low accuracy if persistent symptoms are used as the outcome variable. The alternative explanation that transport itself plays a causal role in adverse outcomes is less plausible. Similarly, the association of decontamination with a decreased risk of medical treatment or objective abnormalities in multiple regression modeling supports the present application of this treatment by first responders.

The ability to make appropriate individual treatment decisions following hazardous materials exposure depends on the accuracy of the initial on-scene information. Because there was not complete agreement between this information and subsequent reports, caution is indicated

when using this information. Chemical identification was more reliable than chemical quantity, which was often unknown. The lack of quantity information makes exposure assessment difficult for most of the incidents evaluated in this study.

No comparative health outcome study following hazardous materials exposure is available in the medical literature. Previous studies in Washington State and Massachusetts have described acute symptoms following a range of different chemical exposures, with findings similar to the present study but without follow-up information.[3,10,17] Other studies have reported acute symptoms following exposures limited to specific chemicals, such as metam-sodium,[18] ethyldichlorsilane,[19] hydrofluoric acid,[20] and methyl isocyanate,[7] and some of these studies included description of persistent health effects. As expected from the irritant and corrosive nature of these chemicals and the inhalation route of exposure, respiratory and mucous membrane symptoms were prevalent, although other outcomes also occurred. However, these specific incidents were large-scale and affected many people and therefore were not typical of the generally smaller incidents described in our present study.

The present study has several limitations. The extent of chemical exposure could not be quantified. It is likely that a number of patients evaluated and treated had minimal exposure. Therefore the focus of this article was on hazardous materials incidents, rather than "exposures." Because the chemicals released in hazardous materials incidents vary greatly, it was necessary to group them for analytical purposes. If a larger sample size were available, it might be more informative to focus on incidents involving a single chemical, such as chlorine or ammonia.

No information was available on individuals without contact information. This population may be different from the participating subjects, limiting our ability to generalize the study results to all individuals exposed to hazardous materials. Of individuals with contact information, surveys could be obtained in only 59%, again raising concerns about the generalizability of our results. Because not all patients were evaluated in a health care facility, it is also possible that some asymptomatic patients may have had undiscovered objective medical findings. Because of the lack of previous studies evaluating risk factors for adverse health outcomes following hazardous materials exposure, we used a hypothesis-generating approach to regression analysis, so the findings described here should be considered preliminary and requiring validation in future studies. Although the number of acute symptoms and number of alcoholic drinks per week were excluded from the analysis of time loss because of colinearity, they should be included as potential risk factors in future studies.

The development of persistent symptoms and time loss following a hazardous materials incident was predicted by a number of psychosocial factors. The creation of treatment algorithms or transport criteria that do not consider these psychosocial factors is unlikely to have high accuracy for predicting persistent symptoms or time loss. Because psychosocial factors have a major influence on outcome and may be difficult to determine at the time of initial exposure, developing transport algorithms purely on the basis of objective medical findings may represent a substantial challenge.

In conclusion, both incident characteristics, such as exposure duration and chemical type, and individual characteristics, such as route of exposure, preexisting illness, symptoms, alcohol use, marital status, and decontamination, are variably associated with outcome following hazardous material exposure. Additional research is required to validate the results of this study and to develop improved protocols for the care of individuals exposed to hazardous materials.

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Flashback

"From all accounts, Henry Ford has allowed his millions to turn his head. His unique success has hypnotized him into imagining that he has become a tin god. For the first time in his career, he is now finding it impossible to sell his cars as fast as he could make them, and is undergoing a mild dose of the acute depression which has overtaken innumerable business concerns. It is earnestly to be hoped that this sobering experience will cause Ford to tone down his notions about the superhuman powers of himself and his only son." From *Forbes*, January 22, 1921.

—Adams S, ed. Follow-Through. *Forbes* 2001;167(2):32.