Hazardous Materials Events: Evaluation of Transport to Health Care Facility and Evacuation Decisions

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The study objective was to analyze hazardous materials event and victim factors associated with transportation of victims to a health care facility, and evacuation or shelter-in-place of nearby populations. A retrospective review was conducted on hazardous materials events in Washington State from 1993 to 1997. Bivariate and multiple logistic regression were used to identify risk factors for transportation, evacuation, and shelter-in-place. Over five years, 2,654 victims from 457 events were reported, with 1,859 (70%) transported to a health care facility. Evacuation occurred in 279 (61%) events and shelter-in-place in 14 (3%) events. After excluding 14 deaths, regression analysis indicated that victims with trauma (OR 5.87, 95% CI 1.41-24.5), thermal burns (6.90, 1.15-41.3), dizziness/other CNS symptoms (1.59, 1.00-2.54), and headache (1.54, 1.01-2.35) were most likely to be transported. Chemical releases inside buildings (2.09, 1.06-4.10, compared with transportation events), and involving 3-5 victims (2.86, 1.54-5.31, compared to 1 victim) or ≥6 victims (8.74, 4.01-19.0), were most likely to involve evacuation or shelter-in-place. Events involving sulfuric acid (0.15, 0.05-0.49) and sodium hydroxide (0.19, 0.04-0.94) were least likely to involve evacuation or shelter-in-place. Prehospital decisions to transport victims to a health care facility and evacuate or shelter-in-place nearby populations are associated with event and victim factors. Further research is needed to determine if these factors also predict need for medical care or removal from exposure, and to develop evidence-based prehospital care protocols for hazardous materials exposure victims. (Am J Emerg Med 2001;19:99-105.

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. Lists of specific hazardous materials have been published.[1] Hazardous materials events involve the uncontrolled release of hazardous materials, including spills, explosions, and fires. Because of their diversity, hazardous materials have a broad range of toxicity, and variable potential for morbidity and mortality. Hazardous materials events are relatively frequent, particularly in areas with high population densities, and range in size from single victim events to community disasters.[2] In 1997, the Agency for Toxic Substances and Disease Registry reported 5,531 hazardous materials events in a 13 state area.[3] These events involved 28 deaths, transportation of 1,261 individuals to a health care facility, and admission of 119 victims. Such events may involve orders to evacuate nearby populations, or to "shelter-in-place," in which people are instructed to stay at home or work, seal their doors and windows, and turn off their ventilation systems.

Field management of hazardous materials victims may be difficult, because of limited exposure information and varying chemical toxicity. Although general guidelines are available,[4-6] there are currently no evidence-based criteria to assist in making prehospital decisions. First responders, such as firefighters and paramedics, are required to evaluate and treat hazardous materials victims at, or close to, the scene of the event. Because of the limited experience of most emergency personnel in evaluating such exposures, a high percentage of victims are transported to health care facilities. This process is expensive, and it is believed that many of these exposure victims can be safely evaluated and released from the scene of the event without additional medical care.[7] In addition, evacuation and shelter-in-place decisions will have associated costs, inconveniences, and potential for injury that should be taken into consideration.

We conducted an analysis of first responder decisions during hazardous materials events. The purpose of this analysis was to identify event and victim factors associated with decisions to transport to a health care facility, evacuate, or shelter-in-place. Once identified, the value of such factors in predicting significant morbidity could then be tested in later studies. This would provide an evidence-based approach for recommending changes in the care of hazardous materials exposure victims.

METHODS

A retrospective review was conducted of hazardous materials events occurring in Washington State from 1993 through 1997. Data were collected by the Washington State Department of Health for the Hazardous Substances Emergency Events Surveillance (HSEES) system with support from the Agency of Toxic Substances and Disease Registry (ATSDR). Hazardous materials events are defined by HSEES as uncontrolled, illegal, or threatened releases of hazardous substances, excluding events involving petroleum products exclusively. Threatened releases are included if the hazard led to an action (eg, evacuation) affecting the health of employees, responders, or the general public. Classification as a

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victim in the HSEES database requires report of at least 1 injury within 24 hours of the release, or death resulting from the event. Subjective injuries reported by victims as well as injuries identified by health care professionals are included. Sources providing information include, but are not limited to, first responders, health care facilities, state agencies, and industry representatives.[3]

This analysis was limited to HSEES events involving human victims. Nineteen events with victims were excluded to maintain consistency in reporting requirements from 1993 to 1997 (1 vehicle release of ethylene glycol, 16 vehicle battery explosions, and 2 PCB spills of less than 5 ppm). Five threatened releases involving victims with trauma or overexertion injuries were also excluded from the analyses, because they did not involve actual chemical releases. An event with more than 1 chemical released was coded as a "multiple chemical release." This is distinguished from a mixed chemical event, which is the release of a premixed group of chemicals. Each unique chemical mixture was considered a separate chemical type.

The analyses focused on four distinct outcomes of interest: victim transport to a health care facility, evacuation, shelter-in-place, and either evacuation or shelter-in-place. Transport was defined as a victim being transported to a health care facility and subsequently observed, treated and released, or admitted. An evacuation was defined as an official ordering people to evacuate the area surrounding the event or evacuation in response to an alarm. Shelter-in-place was defined as an official ordering people to stay indoors rather than evacuating. An official could be an incident commander, fire marshal, plant manager, or other responsible party. One event could have both evacuation and shelter-in-place.

Logistic regression models[8] were created for the outcome variable transport to a health care facility. The method of generalized estimating equations (GEE) was used to account for correlation between victims from the same event.[9] An exchangeable correlation matrix was used within events. Victims who died were excluded from this analysis. The rationale for this exclusion was that if patients died at the scene, they would not be transported to a health care facility, and the HSEES database did not distinguish between victims dead at the scene or dying at a later time. Victims missing age or sex data were included in all analyses except for those analyzing age or gender effects.

Predictor variables for each victim included age, sex, first responder or not, and injury (type and number). Age was categorized into 4 groups: 0 to 10, 11 to 17, 18 to 64, and ≥65 years. A responder was defined as a person who fit into one of the following categories: firefighter, police, EMT, hospital personnel, or company response team member. Injury type included trauma, respiratory system irritation problems (sore throat, chemical bronchitis, shortness of breath), eye irritation, skin irritation (rash, blistering), chemical burns, thermal burns, gastrointestinal problems (nausea, vomiting, diarrhea, abdominal pain), dizziness or other central nervous system (CNS) symptoms (numbness, tingling, loss of consciousness, sweats, tunnel vision, light sensitivity, fatigue), headache, heat stress, heart problems (chest pain, angina, tightness of chest), and other. For this analysis, shortness of breath was included in respiratory symptoms, in contrast to the HSEES database where it was included in the "other" category through 1997. Number of injuries was categorized into 3 groups: 1, 2, and 3 or more. Predictor variables for each event included chemical released, area description based on zoning (rural, residential, commercial, other), event type (release during transportation, fixed-facility indoor release, fixed-facility outdoor release), presence of fire, year, and number of victims in the event. Number of victims was categorized into 4 groups: 1, 2, 3 to 5, and 6 or more. Each variable was entered into logistic regression models[8] separately at first for bivariate comparison. A multiple logistic regression model was then constructed by starting with each variable that was a significant predictor of transport at the $P < .10$ level in the bivariate models. Variables were then added and removed according to whether the variable was a significant predictor of transport at the $P < .10$ level after adjusting for the other variables in the model.

Logistic regression models were also created for the outcome variables evacuation, shelter-in-place, and evacuation or shelter-in-place. Predictor variables for each event included chemical released, area description, event type, fire, year, and number of victims in the event. Each variable was entered into the model separately at first for bivariate comparison. A multiple logistic regression model was then constructed for evacuation or shelter-in-place by starting with each variable that was a significant predictor of transport at the $P < .10$ level in the bivariate models. Variables were then added and removed according to whether the variable was a significant predictor of transport at the $P < .10$ level after adjusting for the other variables in the model.

RESULTS

From 1993 to 1997, there were 1,974 hazardous materials events in Washington State. In 457 (23%) of the events, at least 1 human victim was present, with a total of 2,654 victims exposed over the 5-year period. Table 1 shows victim outcome by year. Overall, 1,859 (70%) of the exposure victims were transported to a health care facility. For the 296 events with at least 2 human exposure victims, all victims were transported to a health care facility in 179 (60%) events, and none of the victims was transported in another 49 (17%) events. There were only 65 (22%) events where at least 1 victim was transported and at least 1 victim was released directly from the scene. In 3 (1%) events at least 1 victim died at the scene and all of the rest were transported to a health care facility. In all hazardous materials events, a total of 36,287 people were evacuated. No

TABLE 1. Washington State Hazardous Materials Events With Victims

	1993	1994	1995	1996	1997	Total
Events	124	82	92	86	73	457
Victims	607	351	499	579	618	2,654
Deaths	4 (1%)	3 (1%)	5 (1%)	1 (0%)	1 (0%)	14 (1%)
Treated at scene/not transported	152 (25%)	68 (20%)	45 (9%)	74 (13%)	241 (39%)	580 (22%)
Transported/not admitted*	372 (61%)	248 (71%)	402 (81%)	422 (73%)	322 (52%)	1,766 (67%)
Transported/admitted*	8 (1%)	17 (5%)	28 (6%)	20 (4%)	20 (3%)	93 (4%)
Treated by private physician†	71 (12%)	15 (4%)	16 (3%)	19 (3%)	11 (2%)	132 (5%)
Injuries reported by others†	0 (0%)	0 (0%)	3 (1%)	43 (7%)	23 (4%)	69 (3%)

*Transported to a health care facility.
†Treated or reported within 24 hours.

information was available on the number of people ordered to shelter-in-place. In the 14 (out of 39) counties in Washington State that had ≥50 victims from 1993 to 1997, transport rates varied from 25% to 99%, with a median transport rate of 66%.

Among the 457 hazardous materials events with victims, 78 (17%) involved chemical releases outside of an enclosed structure (outdoors) at a fixed-facility, 315 (69%) involved chemical releases inside an enclosed structure (indoors) at a fixed-facility, and 64 (14%) of the releases occurred during transportation of hazardous substances. Evacuation occurred in 33 (42%) of fixed-facility outdoor events, 223 (71%) of fixed-facility indoor events, and 23 (36%) of transportation events. Shelter-in-place occurred in 8 (10%) of fixed-facility outdoor events, 5 (2%) of fixed-facility indoor events, and 1 (2%) transportation event. A combination of evacuation and shelter-in-place occurred in nine events. Evacuation or shelter-in-place occurred more frequently following releases from fixed facilities (66%) than from transportation events (38%) (χ^2 19.21, $P < .001$).

Information on the 10 (out of 169) most frequently released chemicals is listed in Table 2. For multiple chemicals, the number of chemicals released in an event ranged from 2 to 11, with a mean of 3.3 chemicals. From 1993 to 1997, chemicals with the highest percentages of victim transport to a health care facility included carbon monoxide (96%), sulfur dioxide (92%), sodium hydroxide (90%), and ammonia (90%). Chemicals with the lowest percentage of transport included multiple chemicals (42%) and tear gas (o-chlorobenzylidene malononitrile) (53%). Table 3 lists the frequency of the most commonly reported injuries for the 16 chemicals with 25 or more victims. Symptoms of victims

TABLE 2. Victim Events, Victims, and Transport* Rates for the Most Frequently Released Chemicals

	1993	1994	1995	1996	1997	Total
Multiple chemicals†						
Events	12	3	10	12	8	45
Victims	24	35	38	77	205	379
Transported	92%	91%	61%	64%	17%	42%
Ammonia†						
Events	8	6	9	9	5	37
Victims	13	11	30	125	16	195
Transported	54%	36%	87%	98%	100%	90%
Chlorine						
Events	4	9	6	11	4	34
Victims	35	33	20	35	12	135
Transported	86%	88%	80%	54%	33%	73%
Tear gas‡						
Events	10	5	4	3	10	32
Victims	101	62	18	65	122	368
Transported	42%	76%	72%	45%	52%	53%
Sulfuric acid						
Events	9	6	1	3	4	23
Victims	14	10	1	5	10	40
Transported	50%	80%	100%	100%	70%	70%
Carbon monoxide						
Events	0	1	5	6	6	18
Victims	0	27	33	88	138	286
Transported	0%	100%	91%	93%	98%	96%
Sodium hydroxide						
Events	4	2	0	3	2	11
Victims	11	3	0	32	2	48
Transported	82%	67%	0	97%	50%	90%
Freon NOS§						
Events	4	2	1	4	0	11
Victims	11	9	15	18	0	53
Transported	73%	33%	93%	83%	0%	75%
Sulfur dioxide						
Events	2	3	2	1	2	10
Victims	9	5	5	2	4	25
Transported	100%	100%	60%	100%	100%	92%
Hydrochloric acid						
Events	3	3	1	0	2	9
Victims	7	6	3	0	2	18
Transported	57%	83%	100%	0%	0%	67%

*Transport to a health care facility.
†Victim counts do not include deaths (5 in multiple chemical events and 5 in ammonia events).
‡O-chlorobenzylidene malononitrile.
§NOS, not otherwise specified.

TABLE 3. Injury Type* for Chemicals With 25 or More Victims

Chemical	Victims	Respiratory	Eye Irritation	Skin Irritation	Chemical Burns	Thermal Burns	Gastrointestinal	Dizziness/Other CNS	Headache
Multiple chemicals	384	83%	13%	9%	2%	2%	9%	5%	12%
Tear gas†	368	91%	73%	13%	<1%	0	10%	8%	5%
Carbon monoxide	286	26%	3%	0	0	0	54%	62%	78%
Ammonia	200	90%	22%	4%	5%	5%	14%	1%	16%
Oxides of nitrogen	138	82%	22%	6%	0	0	12%	7%	16%
Chlorine	135	96%	30%	2%	1%	0	4%	7%	0
Freon NOS‡	53	85%	49%	0	2%	0	43%	19%	19%
Fiberglass	51	92%	4%	90%	0	0	8%	12%	18%
Sodium hydroxide	48	27%	54%	4%	17%	0	50%	4%	4%
Propylene glycol monomethyl ether acetate	42	29%	2%	0	0	0	81%	71%	90%
Sulfuric acid	40	45%	13%	5%	48%	0	20%	5%	0
Indeterminate§	37	70%	65%	0	0	0	30%	30%	32%
Copper nitrate	36	100%	100%	0	0	0	0	0	100%
Ammonium sulfide	31	97%	55%	0	3%	0	0	0	0
Nitric acid	31	94%	0	3%	0	0	0	35%	19%
Sulfur dioxide	25	68%	48%	4%	4%	8%	0	0	12%
All other chemicals	749	53%	26%	8%	4%	1%	31%	23%	30%
Total	2,654	69%	29%	8%	3%	1%	23%	18%	26%

*Injury type limited to 8 out of the 12 most frequently reported categories.
†O-chlorobenzylidene malononitrile.
‡NOS, not otherwise specified.
§Indeterminate, reported substance does not match with known chemical names.

who died were included in this table. Respiratory symptoms were the most frequently reported symptoms.

The results of the bivariate logistic GEE models for transport are given in Table 4. Analysis was limited to 2,640 surviving victims in 451 events. The injuries trauma, gastrointestinal symptoms, dizziness/other CNS symptoms, and headache were statistically associated ($P < .05$) with increased likelihood of transport. Victims with a combination of 3 or more symptoms were also at increased risk for transport. Results of the multiple logistic regression model are presented in Table 5. Although the presence of thermal burns was not associated with transport in the bivariate model at the $P < .10$ level, it improved the multiple logistic regression model fit and was therefore added to the model. The risks of being transported were significantly higher for victims with trauma, thermal burns, dizziness/other CNS symptoms, or headache.

To control for the tendency of first responders to transport either all or none of the victims present at an event, a subanalysis restricted to the 65 events with at least 1 victim released from the scene and 1 person transported to a health care facility was performed. Some of the same factors were statistically associated with increased likelihood of transport to a health care facility, including gastrointestinal symptoms (OR 3.48, 95% CI 1.13 to 10.8), dizziness/other CNS symptoms (OR 2.44, 95% CI 1.02 to 5.85), headache (OR 2.58, 95% CI 1.09 to 6.10), and ≥3 symptoms (OR 3.11, 95% CI 1.06 to 9.07). However, in this subanalysis, additional factors became significantly associated with transport, including events involving sodium hydroxide (OR 11.9, 95% CI 4.92 to 28.9), rural events (OR 3.95, 95% CI 2.07 to 7.51), and exposures during 1995 (OR 14.2, 95% CI 1.87 to 107, compared with year 1997). In addition, trauma lost statistical significance. No statistically significant associations were found with multiple logistic regression modeling, although the transport rates were elevated for gastrointestinal symptoms, chemical burns, and headache.

Risk factors for evacuation and shelter-in-place were also evaluated using bivariate logistic regression. Significantly higher rates of evacuation or shelter-in-place, were associated with events involving tear gas (o-chlorobenzylidene malononitrile) (OR 9.15, 95% CI 2.13 to 39.2), fixed-facility indoor events (OR 4.10, 95% CI 2.34 to 7.19), and greater than 3 victims (for 3 to 5 victims OR 3.89, 95% CI 2.22 to 6.80, for ≥6 victims OR 12.5, 95% CI 6.08 to 25.8). Events involving sulfuric acid (OR 0.13, 95% CI 0.04 to 0.39) or sodium hydroxide (OR 0.23, 95% CI 0.06 to 0.89), and events in rural areas (OR 0.17, 95% CI 0.08 to 0.42) were significantly associated with a decreased likelihood of evacuation or shelter-in-place. The results of bivariate logistic analysis for evacuation alone were almost identical, with the exception of hydrochloric acid events showing a statistically significant decreased rate of evacuation (OR 0.18, 95% CI 0.04 to 0.89). In bivariate regression analysis of shelter-in-place, limited to 14 events, events involving multiple chemicals (OR 5.44, 95% CI 1.31 to 22.6) and sulfur dioxide (OR 13.9, 95% CI 2.22 to 87.6) had a statistically significant increased rate. A multiple logistic regression model was constructed for evacuation or shelter-in-place, as presented in Table 6. Rates were statistically increased for fixed-facility indoor events and events with 3 or more victims. Events involving sulfuric acid and sodium hydroxide were statistically associated with a decreased rate of evacuation or shelter-in-place.

TABLE 4. Bivariate Logistic Regression Analysis of Victim and Event Risk Factors for Transport to a Health Care Facility

Variable	Value	Victims	Transported	Transport ratio	OR (95% CI)*
Age†	0-10	182	100	.55	1.08 (0.84-1.40)
	11-17	402	285	.71	0.84 (0.65-1.09)
	18-64	1,518	1,146	.75	1.00
	65-100	20	12	.60	0.72 (0.29-1.79)
Sex†	Male	1,330	927	.70	1.06 (0.95-1.18)
	Female	1,215	882	.73	1.00
Responder	Yes	185	152	.82	1.49 (0.79-2.79)
	No	2,455	1,707	.70	1.00
No. victims	1	157	101	.64	0.71 (0.43-1.16)
	2	190	139	.73	1.08 (0.62-1.89)
	3-5	356	270	.76	1.23 (0.70-2.15)
	6-180	1,937	1,349	.70	1.00
Trauma	Yes	39	35	.90	**3.68 (1.03-13.1)**
	No	2,601	1,824	.70	1.00
Respiratory	Yes	1,859	1,230	.66	0.82 (0.66-1.03)
	No	781	629	.81	1.00
Eye irritation	Yes	782	542	.69	0.84 (0.65-1.08)
	No	1,858	1,317	.71	1.00
Skin irritation	Yes	212	116	.55	1.08 (0.59-2.00)
	No	2,428	1,743	.72	1.00
Chemical burns	Yes	80	60	.75	1.25 (0.70-2.24)
	No	2,560	1,799	.70	1.00
Thermal burns	Yes	18	17	.94	3.55 (0.73-17.2)
	No	2,622	1,842	.70	1.00
Gastrointestinal	Yes	606	494	.82	**2.00 (1.03-3.88)**
	No	2,034	1,365	.67	1.00
Dizziness/Other CNS	Yes	487	410	.84	**1.67 (1.04-2.69)**
	No	2,153	1,449	.67	1.00
Headache	Yes	682	583	.85	**1.68 (1.05-2.70)**
	No	1,958	1,276	.65	1.00
Heat stress	Yes	4	1	.25	0.12 (0.00-4.16)
	No	2,636	1,858	.70	1.00
Heart	Yes	31	22	.71	1.04 (0.58-1.87)
	No	2,609	1,837	.70	1.00
Other	Yes	46	31	.67	0.88 (0.59-1.31)
	No	2,594	1,828	.70	1.00
No. symptoms	1	1,111	700	.63	1.00
	2	970	732	.75	1.33 (0.82-2.15)
	3-6	559	427	.76	**1.99 (1.15-3.45)**
Chemical	Multiple	379	161	.42	1.37 (0.68-2.75)
	Ammonia	195	176	.90	1.55 (0.68-3.53)
	Chlorine	135	98	.73	0.82 (0.41-1.62)
	Tear gas‡	368	194	.53	0.56 (0.29-1.08)
	Sulfuric acid	40	28	.70	0.85 (0.34-2.13)
	Carbon monoxide	286	274	.96	2.63 (0.78-8.83)
	Sodium hydroxide	48	43	.90	1.10 (0.32-3.81)
	Freon NOS§	53	40	.75	1.04 (0.31-3.54)
	Sulfur dioxide	25	23	.92	3.81 (0.47-30.7)
	Hydrochloric acid	18	12	.67	0.48 (0.12-1.85)
	Other	1,093	810	.74	1.00
Area	Other	295	210	.71	0.92 (0.48-1.79)
	Residential	392	306	.78	0.76 (0.46-1.25)
	Rural	50	42	.84	2.05 (0.72-5.81)
	Commercial	1,903	1,301	.68	1.00
Location	Transportation	154	101	.66	1.07 (0.53-2.16)
	Fixed-facility, indoor	1,812	1,349	.74	1.24 (0.74-2.08)
	Fixed-facility, outdoor	674	409	.61	1.00
Fire	Yes	169	134	.79	1.17 (0.62-2.22)
	No	2,471	1,725	.70	1.00
Year	1993	603	380	.63	0.72 (0.40-1.28)
	1994	348	265	.76	1.05 (0.55-1.99)
	1995	494	430	.87	1.51 (0.78-2.91)
	1996	578	442	.76	1.32 (0.71-2.48)
	1997	617	342	.55	1.00

NOTE. Dead victims excluded from analysis.
*Odds ratio and 95% confidence intervals obtained using logistic regression and adjusted for correlation using GEE, but not adjusted for any other variables.
†An additional 518 victims are missing age data, and 95 are also missing gender data.
‡Tear gas, O-chlorobenzylidene malononitrile.
§NOS, not otherwise specified.

TABLE 5. Multiple Logistic Regression Model for Transport to a Health Care Facility

Variable	Value	Victims	Transported	OR (95% CI)*
Trauma	Yes	39	35	5.87 (1.41-24.5)
	No	2,601	1,824	1.00
Thermal burns	Yes	18	17	6.90 (1.15-41.3)
	No	2,622	1,842	1.00
Dizziness/Other CNS	Yes	487	410	1.59 (1.00-2.54)
	No	2,153	1,449	1.00
Gastrointestinal	Yes	606	494	1.96 (0.96-4.00)
	No	2,034	1,365	1.00
Headache	Yes	682	583	1.54 (1.01-2.35)
	No	1,958	1,276	1.00

NOTE. Dead victims excluded from analysis.
*Adjusted for correlation using GEE.

DISCUSSION

Our findings indicate that victim transport to a health care facility is extremely common in hazardous materials events. The 70% transport rate in Washington state is consistent with national trends, with a 66% average transport rate of all victims reported in 13 states in 1997,[3] and exceeds the rates reported in previous Washington state surveys.[7,10] In our analysis, both event and victim specific factors were associated with the decision to transport to a health care facility. Trauma, thermal burns, dizziness/other CNS symptoms, and headache were found to be associated with victim transport in a "best-fit" logistic regression model. Clearly trauma and thermal burns are significant injuries, and in the majority of cases would be expected to require evaluation and potentially treatment at a health care facility. In contrast, dizziness, other CNS symptoms and headache are less specific, and may occur in the absence of significant toxic exposure.[11-15] Although dizziness, other CNS symptoms and headache are commonly described after exposures with primary CNS toxicity (eg, carbon monoxide and organic solvents), their physiologic significance in other settings is less clear. Respiratory symptoms were most common, as would be expected given the frequent release of respiratory irritants in hazardous materials events.[7,10,16]

Other victim factors were not associated with transport decisions. Although victims at age extremes may be more sensitive to the effects of toxic exposures,[17] no association between age and decision to transport was observed. It is possible that these individuals were exposed to lower chemical concentrations than occupationally exposed groups (aged 18 to 64), affecting prehospital transport decisions. Although victim past and present medical history may have affected transport decisions, this medical information was not available for analysis.

No chemicals were specifically associated with transport of victims to a health care facility in our multiple logistic regression model. However, a great deal of variability in transport rate was found between spills of different chemicals. In addition, a significantly elevated risk of transport in sodium hydroxide events was found in the subanalysis restricted to the 65 events with at least 1 victim released from the scene and 1 person transported. Many of the most commonly released chemicals in our analysis, including ammonia, chlorine, sulfuric acid, tear gas, sulfur dioxide, and hydrochloric acid are irritants with relatively high water solubility. Given these chemical characteristics, symptoms should occur immediately on exposure. Unless the victim is unable to escape or is exposed to high chemical concentrations, the extent of injury will be apparent immediately. Therefore victims exposed to these chemicals have the potential to be observed at triage sites established near the event site. Patients with resolution of symptoms after a short interval could be safely sent home with appropriate instructions to seek evaluation at a health care facility if additional symptoms developed. In this analysis, the lack of significant association between respiratory symptoms and transport rate makes it difficult to determine if such an approach is currently being used.

The benefit of a high transport rate is that victims are more likely to receive necessary medical care. However, of the 1,859 victims reported in our analysis as transported, only 93 (5%) were admitted to a health care facility. Because the majority of hazardous materials events do not appear to result in significant morbidity, our findings raise some concerns regarding the cost-effectiveness of the current approach resulting in high transport rates. This is emphasized by a previous study of hazardous materials events, which found reduced victim transport, and by inference decreased costs, associated with first responder contact with a regional Poison Center.[7]

TABLE 6. Multiple Logistic Regression Model for Evacuation or Shelter-in-Place Order

Variable	Value	Events	Evacuation or Shelter-in-Place	OR (95% CI)*
Chemical	Multiple	45	24	0.71 (0.34-1.49)
	Ammonia	37	24	1.71 (0.74-3.92)
	Chlorine	34	24	1.34 (0.56-3.18)
	Tear gas†	32	30	4.14 (0.92-18.7)
	Sulfuric acid	23	4	0.15 (0.05-0.49)
	Carbon monoxide	18	14	0.97 (0.27-3.50)
	Sodium hydroxide	11	3	0.19 (0.04-0.94)
	Freon NOS‡	11	10	3.65 (0.44-30.5)
	Sulfur dioxide	10	7	1.28 (0.30-5.45)
	Hydrochloric	9	3	0.41 (0.09-1.85)
	Other	227	141	1.00
Area	Other	46	26	1.73 (0.80-3.71)
	Commercial	303	196	1.00
	Residential	79	55	2.10 (0.86-5.14)
	Rural	29	7	0.45 (0.14-1.46)
Location	Transportation	64	24	1.00
	Fixed-facility, indoor	315	224	2.09 (1.06-4.10)
	Fixed-facility, outdoor	78	36	0.93 (0.42-2.06)
Victims	1	161	69	1.00
	2	98	51	1.10 (0.63-1.91)
	3-5	94	70	2.86 (1.54-5.31)
	6-180	104	94	8.74 (4.01-19.0)

*Adjusted for correlation using GEE.
†O-chlorobenzylidene malononitrile.
‡NOS, not otherwise specified.

Evacuation was common in this analysis, occurring in 61% of the victim events, whereas shelter-in-place was much less frequent, occurring in only 3% of events. Typically, first responders use the North American Emergency Response Guidebook for information on whether evacuation is needed, based on the chemical, amount of the spill, and distance from the source.[6] In the future, the Environmental Protection Agency mandated risk management program[18] for fixed-facility chemical sources may also be used in association with computer modeling of releases to determine evacuation zones. Given the transient nature of many chemical releases, it was interesting to note that so few incidents involved shelter-in-place. This finding may reflect the high percentage of fixed-facility indoor releases (69%), rather than releases to the open air.

Decisions to evacuate or shelter-in-place were strongly associated with event-specific factors. Events involving chemicals with relatively lower vapor pressures and hazard indices, such as sulfuric acid, sodium hydroxide, and hydrochloric acid, were associated with a lower risk of evacuation, as were events in rural areas with less nearby population. Fixed-facility indoor events were more likely to involve evacuation, as would be expected given the increased potential for exposure concentrations to reach injurious levels.

Studies to date have not specifically assessed medical treatment decisions of first responders in hazardous materials incidents. Kales and associates have evaluated hazardous materials events in Massachusetts for cause, contents, and health effects with similar findings to our analysis, although these studies included petroleum product (hydrocarbon) events.[16,19,20] Previous studies in Washington State also found similar patterns of exposures and health effects.[7,10] Our findings indicate that both event related and victim symptom factors are associated with decisions to transport. Although the appropriateness of field judgements is key to the effective management of hazardous materials events, these have received minimal attention to date.

The current analysis has several limitations. The first is the inability to obtain medical outcome information other than death, initial symptoms, and admission to a health care facility. Although transport decisions can be analyzed, their appropriateness cannot be evaluated. Second, the HSEES database tends to exclude less significant exposures without associated symptoms. Thus the decision to transport based on presence or absence of symptoms could not be definitively addressed. Third, it is difficult to completely control for confounding by event when evaluating decisions based on victim symptoms, with the most problematic example being the tendency of first responders to transport either all or none of the victims at an event. Fourth, data on use of specific prehospital medical treatment protocols were not available, and therefore assessment of the effect of such protocols was beyond the scope of this analysis.

In conclusion, this analysis suggests that first responder decisions to transport victims to health care facilities are associated with specific event and victim factors. Some of these decisions are consistent with current medical opinion, such as transporting victims with trauma. The efficacy of transporting victims with less specific symptoms of headache, dizziness, and other CNS symptoms requires further evaluation. Future research should focus on both event and victim characteristics that are associated with increased morbidity, to formulate transport algorithms and an evidence-based approach to the management of hazardous materials events.

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