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Posttraumatic stress and tendency to panic in the aftermath of the chlorine gas disaster in Graniteville, South Carolina

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Abstract

Purpose—Relatively little is known about psychological effects of environmental hazard disasters. This study examines the development of posttraumatic stress (PTS) and tendency to limited panic attack after a large chlorine spill in a community.

Methods—In January 2005, a large chlorine spill occurred in Graniteville, SC. Acute injuries were quantified on an ordinal severity scale. Eight to ten months later, participating victims completed the Short Screening Scale for PTSD ($n = 225$) and the Holden Psychological Screening Inventory (HPSI) ($n = 193$) as part of a public health intervention. Forced expiratory volume in 1 s (FEV_1) and forced vital capacity were likewise measured via spirometry. Two sets of univariate logistic regression models were fit to detect independent effects of each potential covariate and risk factor on PTS score and tendency to panic. A supplemental analysis examined whether poor lung function may be a confounder and/or effect modifier of the effect of acute injury on PTS score and panic.

Results—Of those who completed psychological screening, 36.9% exhibited PTS symptoms. FEV_1, acute injury, and the HPSI psychiatric subscale were independently associated with increased PTS score. Acute injury severity scale and female sex were associated with tendency to panic. Immediate acute injury severity and poor lung function later were independently associated with PTS symptomotology.

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Conclusions—The high prevalence of PTS and endorsement of tendency to panic within our sample show a need for mental health treatment after a chemical hazard disaster. Mental health personnel should be considerate of those with serious physical injuries.

Keywords

Chlorine; Disaster; Posttraumatic stress disorder; Panic

Introduction

Technological advances have fostered conditions wherein industrial accidents have become a public health concern [1]. These tragic occurrences require the application of scientific methods to further our understanding of their adverse effects on human health to improve emergency management efforts and reduce the toll on human lives.

An accidental chemical exposure to a human population can provide substantial scientific information on the effects of this type of chemical exposure on human health [2]. The effects of a chemical exposure disaster include psychological effects of the traumatic stress concomitant with physical effects of the toxic chemical [3]. Unless carefully assessed, the physical health effects associated with a chemical exposure event may be confounded by comorbid effects of traumatic stress due to the threatening character of the exposure event [4–8].

In comparison to the emphasis given to physical and somatic injury following chemical release disasters (including neurological dysfunction), the extent and severity of psychological effects such as posttraumatic stress (PTS) reactions or tendency to have panic attacks have not been well studied [9]. For example, little or no psychological sequelae other than objective cognitive and neurobehavioral effects (e.g., reaction time, psychomotor, and eyeblink conditioning) have been reported for chemical disasters such as the large-scale release of the hazardous chemical methyl-iso-cyanate in Bhopal, India in 1984 [10–12] and the chlorine and cresylate release after a train derailment in Alberton, Montana in 1996 [13–16]. Chemical spill-based studies have considered clinically significant psychopathology involving spills caused by train derailment in northern California in 1991 [17] and Eunice, Louisiana in 2000 [18]. Neither study's psychological findings adjusted for the physical injury that may have exacerbated their effects.

At 2:48 on the morning of 6 January 2005, a freight train traveling 77 km/h was inadvertently switched onto an industrial spur and immediately collided with a parked train outside of a textile mill in Graniteville, an unincorporated cotton mill-town in South Carolina [19]. Three chlorine tank train cars immediately derailed, one of which was punctured and leaked over 54,000 kg of liquid chlorine. The chlorine quickly boiled and produced a thick cloud of gas. The calm weather that night allowed the plume to spread throughout the area where the community slept. As a result of the chlorine exposure, 9 people died, 72 were hospitalized, and at least 840 people received medical treatment at area hospitals and physicians' offices. At least 220 others experienced symptoms but did not seek medical attention immediately.

Many of this study's participants either directly experienced the traumatic event or experienced second-hand trauma such as serious illness or death of a loved one. Because this event comprised both psychological and physical injury, we can address the relationship between these two factors as well as their association with actual chlorine exposure using a prospective cohort study design. In this study, we will examine the effect of physical traumatic stress measures (e.g., direct peak exposure, objective pulmonary dysfunction, and acute physical outcomes) on the development of PTS and tendency to panic attacks in a subset of the Graniteville disaster population.

Methods

Plume model

Chlorine exposure estimates were calculated from a plume dispersion model. Our plume model was developed using the same source term and Industrial Transportation Module within the Hazard Prediction and Assessment Capability (HPAC) version 4.04 SP3 software that others have used for the same accident [20, 21]. The surface dosage plot was transferred into ArcMap 8.3. Estimates of mean chlorine concentration [kg s/m3] at each location at 1.5 m above ground level were output from the HPAC model every 1 min. Exposure estimates had a log-normal distribution. Exposure estimates were aggregated to 30-min acute exposure guideline levels (AEGLs) for presentation and comparison with current United States Environmental Protection Agency (US EPA) exposure guidelines [22]. Registrants were likely exposed to a wide range of chlorine gas concentrations—from no exposure to exposure over 1,000 ppm for at least 1 min as estimated outdoors (data not shown). Chlorine exposures were categorized in terms of AEGLs, ranging from AEGL0 (<0.5 ppm) to AEGL3 (>28 ppm) for 30 min of sustained exposure.

Immediate participant information

Following the chlorine spill, more than 840 people in Graniteville sought medical attention. At least 220 others experienced symptoms but did not receive medical treatment. Individuals' acute injuries were quantified on an ordinal scale of acute injury severity. The effective range of the scale in our sample was 1–9, with 1 being no health services utilized and 10 being dead. A thorough description of the immediate health effects has been provided elsewhere as a case-series study of the hospitalized patients [23]. An acute injury value of 2 was given to a person who visited a physician, a score of 3–5 represents a visit to the emergency department (ED) and no treatment, moderate treatment, and significant treatment, respectively; a score of 6 was given if there were multiple ED visits but no hospitalization; a score of 7–8 represents a person who was hospitalized 1–2 nights and 3 or more nights, respectively; a score of 9 represents ventilator or ICU treatment.

Follow-up participant information

An event health registry was opened in June 2005 for all people who lived in, traveled through, or responded to the accident area during the time of the incident who were in need of public health services [24], and it was through this registry and subsequent health screening of some registrants that all relevant follow-up health outcome data were collected for this study. Because the registry was created by successfully integrating community engagement and the public health service efforts, those in the registry were not only demographically representative of the Graniteville community but also randomly geographically distributed within the community [19].

In brief, victims called the registry and completed a brief telephone interview in which information was solicited on locations of exposure, basic demographics, newly developed or worsened symptoms, and whether the individual sought medical treatment immediately following the chlorine spill. From mid-August to the end of October, 2005, the South Carolina Department of Health and Environmental Control (SCDHEC) offered a free medical screening to all persons enrolled in the registry who were exposed within 1 mile of the accident site. Relevant details of the services provided during the health screenings are described here, while a more thorough explanation of this public health intervention will be presented elsewhere.

Graniteville health screenings included: a physical examination focused on medical signs of illness/injury resulting from chlorine exposure, a vital signs assessment, medical and exposure history, current lung function (spirometry, exhaled breath condensate collection and pH analysis), and psychological assessments. The health screenings were performed at two area churches (one predominantly black, one predominantly white) and one local mental health clinic on a rotating schedule. At the conclusion of each screening, a physician reviewed the results with each patient and made follow-up recommendations, as appropriate with respect to any observed physical and/or psychological illness. Registrants voluntarily consented to participate in the health screenings and no one was excluded from the registry due to age, ethnicity, socioeconomic status, or spoken language. However, children under age 14 did not complete the psychological portion of the screening because the assessment instruments were not designed for use with children. Demented elderly individuals and those with known or suspected cognitive impairment did not receive the psychological screening either. Ethics approval was obtained from both the SCDHEC and from University of South Carolina Institutional Review Boards prior to initiating the public health registry and screening services.

The Psychological screening consisted of the Short Screening Scale for PTSD (SSPTSD) [25] and the Holden Psychological Screening Inventory (HPSI) [26]. These psychometric instruments provided the two mental health outcomes used in our analyses: PTS score and tendency to panic. Two hundred twenty-five participants completed the SSPTSD, which is a validated seven-item (yes/no) clinician-administered interview measure [27]. The items ask about symptoms in connection with a traumatic event and the scale uses a cutoff score of four or more for predicting diagnostic PTSD. However, our on-the-ground mental health screening of victims was designed to provide clinical decision-making information for referral of individuals for further mental health assessment and treatment. For this reason, we were over-inclusive and used an SSPTSD cutoff score of 3 for referral. The instrument has been widely used in many populations to identify potential or likely PTSD outcomes, and it is well suited for use in primary care settings and the acute aftermath of trauma [28, 29].

The HPSI is a 36-item psychological/psychiatric screening instrument that has been widely used in the US and is suitable for use with adult community samples [30, 31]. Each item is rated on a 5-point scale, from 0 to 4, and the items are then grouped into 3 subscales of 12 items each: (1) depression (sad, withdrawal, self-blame), (2) psychiatric symptomatology (anxiety, somatization, psychoticism), and (3) social symptomatology (interpersonal problems and alienation, impulsivity, and deviance). The HPSI has a Total Psychopathology Scale as well, which is the sum of the three subscales. Raw scores are converted to *t* scores based on normative population data. While the HPSI quantifies relatively enduring psychopathology, it can also be used to measure individual change [32]. Invalidity of HPSI respondent profiles (e.g., exaggeration or hyperbole, fabrication, omission of items, and/or poor question comprehension) was identified using established cutoff scores. Participants with invalid scores were excluded from data analysis ($n = 10$).

The panic indicator was simply derived from one single item of the HPSI (“Do you panic more easily than others?”), where a response of either “agree” (3) or “strongly agree” (4) was used to indicate endorsement of a positive response. We used this item because the tendency to have panic attacks is responsive to change as a result of environmental stress. One hundred ninety-three participants completed the panic item of the HPSI.

Each participant completed spirometry testing according to fixed standardized protocols [33–35]. Two measures from this testing were used in our analyses herein: forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC). FEV_1 is a measure of the amount of air that a person can forcibly exhale in the first 1 s of exhalation and FVC measures the total amount of air that a person can forcibly exhale in 6 s after full inspiration. FEV_1 and FVC were dichotomized with a cut point at 80% of predicted normal value, because less than 80% predicted normal value is a commonly used indicator of potential obstructive and restrictive respiratory defects, respectively. Other variables used in our analysis were age, education, race, gender, and, in modeling PTS score, the HPSI subscales.

Analyses

Spearman and Pearson correlation matrices were calculated to assess the correlations of both PTS score and tendency to panic with potential covariates (acute injury, chlorine exposure, age, and education) and risk factors (race, gender, and current respiratory defects). First, two sets of univariate logistic regression models were fit to detect the independent effect of each potential covariate and risk factor on PTS score and tendency to panic. One extra univariate model was fit in which HPSI Psychiatric Sub-scale score predicted PTS score. Within each set, the model parameters whose univariate p values were less than 0.2 were included as predictors in the respective final model. The final PTS model was done with multinomial logistic regression, where SSPTSD scores of 3–4 (moderate) and 5–7 (severe) were modeled in relation to the referent group SSPTSD score group 0–2 (none or mild).

A supplemental analysis was completed for further PTS inference. We examined the possibility of poor lung function as a confounder and/or effect modifier of the effect of acute injury on PTS score. All modeling was performed using SAS 9.1 software (SAS Institute, Cary, NC).

Results

The demographic profile of the registry population and the screened sample are shown in Table 1. Both sexes and non-Hispanic blacks and non-Hispanic whites are well represented in our sample. Demographic representation in the study sample did not differ from the subsamples who were screened. The number of individuals endorsing SSPTSD items decreased monotonically from 0 (27.5%) to 7 (3.2%) items, and the cumulative percentage of individuals who did not reach the cutoff (3 or more items on SSPTSD) for referral of PTS was 62.2%. Therefore, over one-third of the people (37.8%) who completed the Psychological screening were likely to demonstrate PTS reaction. Items on the HPSI were occasionally not answered, and identification of invalid responding resulted in the additional elimination of some participants. Two hundred twenty-five and 193 respondents were included in the PTS and tendency to panic modeling, respectively.

Because symptomotology of different psychiatric disorders often overlap, comorbidities are quite common given the presence of one mental illness. This is the case in this study: of the 71 people who reached the cutoff for PTS, 31 (44%) also endorsed (score of three or four) the tendency to panic item. Of the 52 people who endorsed tendency to panic, 31 (60%) also reached PTS threshold. The Cochran–Mantel–Haenszel test reveals these associations as significantly associated, where $p < 0.001$.

PTS model

Because it is a well-established psychometric instrument and it was used in this study as an indicator of pre-exposure psychological/psychiatric conditions, it was determined a priori that one of the three HPSI subscales or Total scale would be included for PTS modeling. Although both the Psychiatric Subscale and Total Psychopathology Scale were strongly correlated with all other subscales (data not shown), the Psychiatric Subscale displayed increased symptom specificity, and therefore it was chosen to enter the PTS model.

Univariate logistic regression—Table 2 shows results of univariate logistic regression models where PTS endorsement is modeled as a function of immediate acute injury, current FEV_1 (<80% predicted FEV_1 vs. >80% predicted FEV_1) and HPSI Psychiatric score, as well as gender, education, age, and race, each modeled separately. Although both FEV_1 and FVC are independently associated with PTS endorsement, FEV_1 displayed a stronger association and therefore FEV_1, as the PFT representative, was chosen for entry in the final model. HPSI Psychiatric score, acute injury and FEV_1 each showed significant independent effects ($p < 0.2$) and therefore were included in the final model.

Multiple logistic regression—In the final model, scores on the SSPTSD were modeled as having three levels (none or mild, moderate, and severe). Multiple collinearity of the three predictor variables in the final equation was low, indicated by their tolerances, variance inflation, and partial correlation in the equation (data not shown). As shown in Table 3, the final PTS model found that HPSI Psychiatric Subscale score, current FEV_1, and acute injury were independently associated with severe PTS symptomatology at 8–10 months post disaster. Very similar results were obtained for the model using FVC rather than FEV_1, except the odds of a severe PTS were lower (4.29 vs. 8.00). Although the parameter estimate for FEV_1 was statistically unstable, Psychiatric score and acute injury were also found to be independently associated with a moderate PTS score.

In a supplementary analysis (data not shown), an interaction term was added to the final PTS model, allowing for current lung function to modify the effect of acute injury on PTS score. The interaction term did not approach statistical significance. Also, we considered whether lung function partially confounded the acute injury–PTS score association by removing current FEV_1 from the final model. The point estimate of acute injury remained unchanged, suggesting FEV_1 does not confound the acute injury–PTS score association. Through this assessment, our data showed that immediate acute injury and current lung function at 8–10 months post disaster independently were associated with increased PTS score.

Tendency to panic model

There were 193 individuals in the registry who completed the psychological screen and answered the HPSI item about tendency to panic. On that tendency to panic item, 141 individuals (73.1%) responded less than or equal to three, while 52 individuals (26.9%) responded either “agree” or “strongly agree”, reaching the a priori tendency to panic threshold.

Univariate logistic regression—Table 4 shows the univariate logistic regression models where tendency to panic is modeled as a function of immediate acute injury, current FEV_1 (<80% predicted FEV_1 vs. >80% predicted FEV_1), as well as gender, education, age, and race, each modeled separately. Acute injury and gender (both $p < 0.20$) were chosen to enter the final tendency to panic model.

Multiple logistic regression—Table 5 shows the result of modeling endorsement of tendency to panic as a function of acute injury and gender. Multiple collinearity of the two predictor variables in the final equation was low, indicated by their tolerances (both >0.999), variance inflation (both equal to 1.0), and partial correlation in the equation (both p values>0.05.). The final model found that gender and acute injury were independently associated with tendency to panic. Females had more than double the odds of reaching the panic tendency threshold, and a one-unit increase in acute injury score was associated with a 35% increase in the odds of an endorsement of ‘agree’ or ‘strongly agree’.

Discussion

Eight to ten months post disaster, 37% of respondents were classified as having a positive PTS screen, about half of which (44%) were considered severe. Twenty-seven percent of all individuals were found to have a positive indication for tendency to panic. Severe PTS score was independently associated with FEV_1, acute injury, and the HPSI Psychiatric Subscale, and the latter two were also associated with a moderate PTS score. Tendency to panic was significantly associated with acute injury and female sex.

For research purposes, PTS ascertainment following a technological disaster has been done in many ways worldwide. Compared to others, the use of a validated scale for PTSD was a particular strength of this study, and the indicative prevalence of PTS within the Graniteville community was well within the expected range at 8–10 months post disaster [36]. Endorsement of tendency to panic was also within the expected range of an anxiety disorder after a disaster [37, 38]. Indication of tendency to panic, as with most anxiety symptomatology, was expected to be more common among women.

Although each of the odds ratio point estimates from the two final models were not far from the null, their interpretations are substantial. In the PTS model, the odds ratios reflect the increase in odds of possible development of PTSD with a single-unit increase in psychiatric subscale score, FEV_1, and acute injury, and the same for acute injury in the final tendency to panic model. Therefore, while a one-unit change in acute injury yields a 70% increase in odds of reporting severe PTS score, a more clinically significant difference of three units increases the likelihood of reporting a severe PTS score by more than three times. The interpretation of odd ratios relating to the HPSI Psychiatric Subscale is similarly remarkable, and, although to a lesser extent, to FEV_1 as well. In other words, not only are these findings statistically significant, they are clinically quite insightful, and speak largely to the need for psychological treatment after a disaster. In a supplemental analysis, our data suggest that immediate acute injury and later lung function separately and independently lead to PTS symptomotology. This supports the idea that both immediate and long-term presence for psychological treatment are necessary to reach all people at risk.

The findings from this study contribute significantly to the post-disaster mental health literature. It is particularly notable that, while both traumatic stress and tendency to panic seem to be a function of physical morbidity caused by the chlorine (as shown by acute injury) neither were associated with the exposure estimates. This finding strengthens the notion that actual involvement, in this case physical involvement, rather than proximity plays the larger role in causing post-disaster mental illness. Therefore, our findings contribute in two major ways. First, the relatively high prevalence of PTS and tendency to panic endorsement within our sample show a great need for mental health treatment after a disaster of this degree. Secondly, our findings suggest that personnel providing mental health services should be especially considerate of those with serious physical injuries. Perhaps even more important than exposure, the physical morbidity resulting from a disaster is a strong risk factor for psychological distress.

This study was not without limitations. First, severity of PTS and tendency to panic endorsement were determined by self-report and they were only measured at one point after the disaster. Alternatively, by actively entering the community, we likely lessened the selection bias that results from employing a clinical sample, and questionnaires were administered by psychiatric social workers from the local Aiken-Barnwell Mental Health Clinic. Second, although the HPSI has been validated and widely used, tendency to panic endorsement was ascertained by only a single item from the HPSI. However, PTS indication through the SSPTSD is widely accepted among the psychiatric epidemiology community.

Third is the issue of statistical precision. Like many psychiatric illnesses, the tendency to panic symptomatology and PTS overlap, but accounting for this by modeling them as correlated outcomes was not statistically feasible with our data due to sample size. Therefore, whether any of the found associations were confounded by the other outcome could not be determined.

Mental health following a technological disaster is a major concern, and PTS and tendency to panic are recognized as two of the more prevalent psychological post-disaster effects. The chlorine spill in Graniteville, South Carolina has provided an insightful perspective on how mental health treatment may be efficiently used in a similar situation. This longitudinal study contributes appreciably to the literature on mental health after a disaster, and its findings may be useful as post-disaster health priorities are continually improved.

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Table 1

Demographics of people who completed the mental health questionnaire and of the original screened sample

	Screened		Study sample	
	n	**%**	***n***	**%**
Total	259	100	225	100
Sex				
Female	144	56	129	57
Male	115	44	96	43
Race	259			
Black, non-Hispanic	82	32	72	32
White, non-Hispanic	164	64	143	64
Other	12	5	9	4
Educational attainment				
<High school grad	110	42	89	40
High school grad	85	33	75	33
Post-HS education	64	25	61	27
Acute injury				
Physician office visit	176	68	150	67
ED visit	69	27	61	27
Hospitalized	10	4	10	4
ICU/ventilator	4	2	4	2

Table 2

Univariate logistic regression results where PTSD endorsement is modeled as a function of covariates and potential risk factors, each modeled separately

Independent variable	OR	95% CI	*p*
Age	1.01	0.99, 1.02	0.48
Race			
White, non-Hispanic	1.00	–	–
Black, non-Hispanic	1.18	0.66, 2.13	0.57
Other	3.72	0.33, 42.04	0.29
Female	1.11	0.65, 1.93	0.69
Education	1.08	0.99, 1.18	0.10
Pulmonary function test			
FEV_1[a]	1.63	0.92, 2.88	0.09
FVC[b]	1.48	0.84, 2.63	0.18
Psychiatric Subscale Score[c]	1.18	1.11, 1.25	<0.01
Acute injury	1.33	1.15, 1.55	<0.01

[a]Forced expiratory volume in 1 s >80% of predicted

[b]Forced vital capacity

[c]From the Holden Psychological Screening Inventory (HPSI)

Table 3

Final multinomial logistic regression results where PTS score is modeled as a function of HPSI's Psychiatric Subscale Score and FEV_1

Variable	SSPTSD score	OR	95% CI	*p*
FEV_1[a]	0–2	1.00	–	–
	3–4	1.35	0.60, 3.07	0.47
	5–7	5.48	1.70, 17.68	<0.01
Psychiatric Subscale Score[b]	0–2	1.00	–	–
	3–4	1.13	1.05, 1.22	<0.01
	5–7	1.31	1.18, 1.44	<0.001
Acute injury	0–2	1.00	–	–
	3–4	1.28	1.03, 1.59	0.02
	5–7	1.70	1.32, 2.17	<0.001

[a]Forced expiratory volume in 1 s >80% of predicted

[b]From the Holden Psychological Screening Inventory (HPSI)

Table 4

Univariate logistic regression results where tendency to panic endorsement is modeled as a function of covariates and potential risk factors, each modeled separately

Independent variable	OR	95% CI	*p*
Age	0.99	0.97, 1.01	0.18
Race			
White, non-Hispanic	1.00	–	–
Black, non-Hispanic	1.52	0.76, 3.03	0.23
Hispanic	1.56	0.14, 17.81	0.72
Female	1.62	0.84, 3.11	0.15
Education	0.94	0.85, 1.04	0.24
Pulmonary function test			
FEV_1[a]	0.85	0.44, 1.62	0.62
FVC[b]	1.06	0.55, 2.03	0.87
Acute injury	1.27	1.09, 1.49	<0.01

[a]Forced expiratory volume in 1 s >80% of predicted

[b]Forced vital capacity

Table 5

Final logistic regression model results where panic endorsement is modeled as a function of gender and acute injury

Variable	OR	95% CI	*p*
Female	2.41	1.25, 5.04	0.02
Acute injury	1.35	1.15, 1.61	<0.01