The Respiratory Health Impact of a Large Urban Fire

ABSTRACT

Objectives. In July 1988, a fire destroyed a huge supermarket warehouse in Richmond, Calif, sending smoke into residential neighborhoods for nearly a week. There was no organized public health response. To evaluate the respiratory health impact on the general population, a survey of emergency room visits and hospital admissions to the two acute-care hospitals serving the population downwind was conducted.

Methods. Medical records of 489 patients meeting specified diagnostic criteria during the week of the fire and several reference periods were abstracted. Ratios of proportions for respiratory diagnoses (i.e., emergency room visits for a given diagnosis/total emergency room visits) were calculated, comparing the fire week with the reference periods, and 1988 mortality data for the area were reviewed.

Results. Ratios of proportions for emergency room visits for asthma and all lower respiratory conditions increased significantly during the fire. Respiratory-related hospitalizations also increased. However, there was no observable increase in respiratory mortality.

Conclusions. This fire was found to have had a moderate impact on the respiratory health of local residents. Public health intervention is indicated to prevent respiratory morbidity when extended exposure to structural fire smoke is predictable. (*Am J Public Health.* 1994;84: 434–438)

Michael Lipsett, MD, JD, Kirsten Waller, MD, MPH, Dennis Shusterman, MD, MPH, Susan Thollaug, RN, MPH, and Wendel Brunner, MD, PhD

Introduction

In July 1988, a fire destroyed a 580 000-sq ft supermarket distribution warehouse in Richmond, Calif. The fire began at 10:00 PM on July 11, emitting huge quantities of smoke through July 16, although it was not completely extinguished until July 19. During this time, smoke drifted north and northeast intermittently into Richmond and San Pablo, cities with a combined population of about 104 000.[1,2] Hundreds of area residents telephoned or visited hospitals and municipal offices complaining about the smoke.[3] Initially, local government agencies believed that this was a typical structural fire, and no official warnings were issued nor were other protective public health measures undertaken.

The public health impact of general population exposures to purely structural fire smoke has not been documented in the published literature. Exposure to smoke from forest fires or from a mixed wildland-suburban fire, however, has recently been reported to result in significant increases in emergency room visits for respiratory conditions.[4,5] Smoke contains various respiratory irritants, including aldehydes, particles, acid aerosols, and other compounds. Analyses of air pollution in urban areas consistently show associations between ambient particle concentrations and a variety of adverse respiratory outcomes (although the composition of smoke is undoubtedly different from routine particle sources).[6–10] Several smoke constituents, in addition, have been demonstrated to provoke bronchoconstriction.[11–13] Exposure to smoke causes acute decrements in pulmonary function and increases in airway reactivity among firefighters and fire victims.[14–16]

The purpose of this study was to estimate any excess respiratory-related hospital use associated with a major urban fire. We surveyed respiratory-related emergency room visits and hospital admissions during the fire period and two reference periods to examine epidemiologically the acute morbidity associated with the Richmond conflagration. We also compared weekly respiratory-related mortality totals for Richmond and San Pablo during and after the fire with weekly totals during the rest of 1988.

Methods

Two acute-care hospitals serving the majority of the population in the area downwind of the fire agreed to participate in this survey. One such hospital is a 42-bed facility (about 36 000 emergency room visits annually) belonging to a health maintenance organization that served 65 000 members at that time; the other is a 246-bed private hospital

Michael Lipsett and Dennis Shusterman are with the California Office of Environmental Health Hazard Assessment, Berkeley. At the time of the study, Kirsten Waller was with the Centers for Disease Control's Division of Field Epidemiology, Atlanta, Ga.; she is currently with the California Department of Health Services, Berkeley. Susan Thollaug is with the Department of Social and Administrative Health Sciences at the University of California's School of Public Health, Berkeley. Wendel Brunner is with the Public Health Division of Contra Costa County's Department of Health Services, Martinez, Calif.

Requests for reprints should be sent to Michael Lipsett, MD, JD, California Office of Environmental Health Hazard Assessment, 2151 Berkeley Way, Berkeley, CA 94704.

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(about 25 000 emergency room visits annually).

The time periods selected for the survey included the fire period (the week of July 12 through 18, 1988), the week following the fire (July 19 through 25, 1988), and two reference weeks (July 8 through 14, 1986 and July 5 through 11, 1988), which were used to control for seasonal and annual trends in emergency room visits and admissions. (We were unable to use a week in 1987 because of a missing emergency room logbook.) All four periods began on a Tuesday to minimize day-of-the-week variability.

Emergency room logbooks and hospital admission listings were reviewed to identify patients who had presented with respiratory complaints or eye irritation, and to calculate total hospital admissions and emergency room visits. The medical records of patients with respiratory-related complaints were then abstracted for age, sex, date and time of emergency room visit or admission, chief complaint, and physician diagnoses. Multiple visits by the same individual were counted as separate visits.

For each emergency room visit or admission, one of the study abstractors assigned an *International Classification of Diseases,* 9th ed. (ICD-9) code to the principal physician diagnosis.[17] The diagnostic categories included the following: nasopharyngitis, sinusitis, pharyngitis, tonsillitis, laryngitis, tracheitis, upper respiratory infection (unspecified), allergic rhinitis, and upper respiratory hypersensitivity reaction (defined as upper respiratory conditions, ICD-9 codes 460–465 and 477); acute bronchitis and bronchiolitis, pneumonia, chronic obstructive pulmonary disease (including chronic bronchitis and emphysema), and asthma (defined as lower respiratory conditions, ICD–9 codes 466, 480–486, 490–492, 496, and 493); exposure to smoke and fumes from a conflagration (ICD–9 codes E891.9 and E891.2); and conjunctivitis (ICD–9 code 372). If the physician's primary diagnosis was incompatible with any of the above ICD categories, the chart was not abstracted. The diagnosis of viral syndrome was coded to one of the appropriate upper or lower respiratory ICD-9 codes, depending on the symptoms and physical findings reported; if the symptoms or findings were not referable to the respiratory tract, the chart was not abstracted. To compare the fire period with the reference periods, patients with an isolated diagnosis of smoke inhalation but with physical findings consistent with another diagnosis were coded to the latter. All emergency room visits and hospital admissions that were not coded to one of these ICD categories were defined as nonrespiratory.

We also evaluated patient charts for evidence of physical findings corroborating the physician diagnoses. We hypothesized that (owing to anxiety, legal concerns, and so forth) people may have been more likely to present with respiratory complaints but without physical findings during the fire period. This might have led to an overestimation of the respiratory effect associated with the fire. To control for this possible bias, we coded each emergency room visit or hospital admission in all time periods as "eligible" (with corroborating physical findings) or "ineligible" (without corroborating physical findings). A diagnosis of bronchitis was always coded as eligible since this diagnosis is often based on history alone. Patients given a diagnosis of smoke inhalation without any abnormal findings on physical, laboratory, or radiological exam were coded as ineligible. Although the abstractors were not blinded to the time period of the visit or admission, each case for which the determination of diagnosis or eligibility code was not straightforward was discussed in group meetings. In these discussions, only the abstractor was aware of when each visit or admission occurred, and codes were assigned based on consensus reached without regard to the time period.

Data entry and analysis were performed using Epi Info.[18] Epidemic curves were constructed by plotting daily numbers of respiratory- and nonrespiratory-related emergency room visits during the prefire, fire, and postfire periods. Ratios of proportions (RPs) of specific diagnostic categories, comparing the fire week to the two prefire reference weeks, were calculated using the following formula for each diagnostic category:

$$RP = \frac{\text{Number of visits for the diagnosis/total visits during the fire period}}{\text{Number of visits for the diagnosis/total visits during the reference periods}}$$

Chi-square tests were performed to test the homogeneity of the proportions of visits for respiratory and nonrespiratory diagnoses between (1) the two reference weeks and (2) the two hospitals.[19] The groups were found to be highly homogeneous; therefore, all results reported comprise pooled data. Confidence intervals (CIs) were computed for all relative proportions using the method of Gart and Nam.[20]

Finally, summary mortality data (obtained from the California Department of Health Services, Health Data and Statistics Branch) for Richmond, San Pablo, and El Sobrante (another small community potentially affected by the smoke) for calendar year 1988 were reviewed to ascertain whether respiratory-related deaths increased during or shortly after the fire period.

Although the smoke was visible for miles, there were unfortunately no relevant air quality data to analyze in conjunction with the health outcome information. The local air pollution control district's closest fixed-site monitor was west and upwind of the plume; the only 24-hour particulate matter sample (measured as total suspended particles) taken at that site during the fire week (on July 14) showed a reading of 52 $\mu g/m^3$, which was slightly greater than readings from samples taken 6 and 12 days earlier (46 $\mu g/m^3$ and 40 $\mu g/m^3$, respectively). No supplemental air monitoring was conducted.

Results

Hospital Survey

There were 489 charts abstracted for the four periods, representing 98.9% of all patients identified from emergency room logbooks and hospital admission records. Of these charts, 451 were for emergency room visits only, 30 were for emergency room visits resulting in hospital admission (counted as both emergency room visits and admissions in the analysis), and 8 were for direct hospital admissions. The distribution of visits and admissions by period is presented in Table 1. The numbers of daily respiratory-related emergency room visits are shown in Figure 1. (There were no differences in numbers of nonrespiratory-related emergency room visits during those periods.)

The ratios of proportions of specific diagnostic categories for emergency room visits are presented in Table 2. Emergency room patients were 1.4 times more

TABLE 1—Numbers of Emergency Room Visits and Hospital Admissions to Two Hospitals in Richmond, Calif, during a Major Urban Fire in 1988 and Several Reference Periods

	Reference Week 1[a]	Reference Week 2[b]	Fire Week[c]	Postfire Week[d]
Total respiratory-related emergency room visits[e]	87	105	160	92
Eligibles	82	100	138	NA
Ineligibles	5	5	22	NA
Nonrespiratory emergency room visits	948	1012	1009	1003
Total emergency room visits	1035	1117	1169	1095
Respiratory-related admissions[f]	9	8	15	6
Nonrespiratory admissions	153	159	149	126
Total admissions	162	167	164	132

[a]July 8–14, 1986.
[b]July 5–11, 1988.
[c]July 12–18, 1988.
[d]July 19–25, 1988 (postfire week data were used only to generate Figure 1 and not to calculate ratios of proportions).
[e]Eligible and ineligible patients combined (see explanation in text).
[f]Eligible patients only. (There were no ineligible hospitalized patients.)

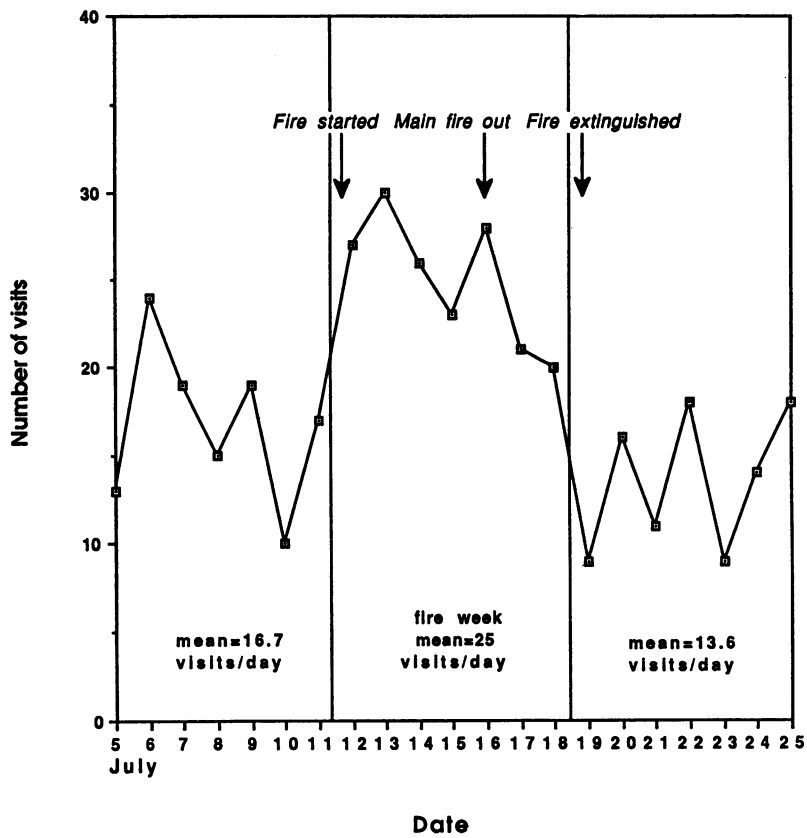

FIGURE 1—Total emergency room visits for respiratory complaints, by day, at two Richmond area hospitals, July 5 through 25, 1988.

likely to receive an eligible respiratory diagnosis during the fire period than during the reference periods. Diagnoses of lower respiratory conditions (RP = 1.55) were increased to a greater extent than those of upper respiratory conditions (RP = 1.20). Among lower respiratory conditions, diagnoses of asthma, bronchitis, and pneumonia were all elevated. The ratio of proportions for conjunctivitis was increased but was not statistically significant (data not shown). We noted no age-related differences in emergency room visits for particular respiratory diagnoses during the fire period compared with the reference periods (data not shown). The proportion of emergency room visits with respiratory diagnoses but without any corroborating physical findings (i.e., ineligible visits) increased 4.05-fold during the fire period; this increase was highly significant (95% CI = 1.92, 8.52).

For hospital admissions, the proportion with diagnoses of respiratory-related conditions was elevated during the fire period, but the confidence interval included unity (RP = 1.77; 95% CI = 0.91, 3.45). Because of the small number of hospitalized patients, we did not calculate ratios of proportions for individual diagnoses.

Community Mortality Data

In the Richmond, San Pablo, and El Sobrante areas, there were no deaths from respiratory causes in the week preceding the fire, one such death during the fire period, four during the week after the fire had been extinguished, and three the following week. All-cause mortality for these weeks totaled 16, 11, 17, and 17, respectively. During calendar year 1988, weekly totals for respiratory causes of death ranged between zero and six (mean = 2.4, SD = 1.5); and for all causes, between 11 and 39 (mean = 23.1, SD = 6.0). Visual inspection of the data indicated that there was no obvious increase in mortality during the 3 weeks after the fire started (data not shown).

Discussion

In this survey, moderate increases in the proportion of hospital visits due to respiratory conditions were found during a 1-week period when an urban population was exposed to substantial quantities of structural fire smoke. However, only the ratio of proportions for asthma was significantly elevated.

Finding an increased proportion of visits for lower respiratory conditions and for asthma in particular was not unexpected, given that smoke, chemical irritants, and airborne particles can all provoke bronchoconstriction.[11–13] In this

study, the vast majority of visits for asthma (96%) during the fire period were made by patients with a previous history of this condition. Thus, the increased ratio of proportions for asthma was not due mainly to isolated episodes of bronchospasm, although such episodes can occur in association with smoke inhalation in people without a history of asthma.[16]

Our results regarding asthma are consistent with a recent report on the impact of forest fire smoke on the general population.[4] However, in that report (which used an emergency room survey design similar to the one reported here) the authors also found significant increases in emergency room visits for upper respiratory conditions. The disparity in results may be due to the substantially greater sample size in the forest fire study, differences in exposure intensity and duration, smoke composition, demographic characteristics, or emergency room triage and diagnostic patterns. Another recent report documenting the health impact of an urban wildfire found that nearly a third of fire-related emergency room visits were for bronchospastic reactions.[5]

Numerous temporal, economic, and individual behavioral factors affect the use of emergency medical services and limit the ability of hospital-based surveys to estimate community effects of acute exposure to smoke or other pollutants. Temporal variation in hospital usage patterns could lead to the selection of inappropriate reference periods and inaccurate estimations of effect. We tried to control for these factors by selecting remote and recent reference periods that paralleled the fire period (i.e., that began on the same day of the week), and by comparing the proportion of visits due to respiratory causes rather than the absolute numbers of respiratory-related visits.

In addition, hospital-based surveys can overestimate an effect if the perception of illness severity or the motivation to seek treatment is increased during periods of exposure. This study was unique in that we tried to control for these factors by distinguishing visits that were corroborated by physical findings from visits that were not. This proved to be the single factor most strongly associated with the fire period, as the proportion of ineligible emergency room visits during that period was four times higher than that in the reference periods.

TABLE 2—Ratios of Proportions for Selected Emergency Room Diagnoses at Two Hospitals in Richmond, Calif, during a Major Urban Fire in 1988

Diagnostic Category	Ratio of Proportions (95% Confidence Interval)	Number of Visits: Fire Period	Number of Visits: Reference Periods
All respiratory conditions[a]	1.40 (1.14, 1.73)	138	182
All upper respiratory conditions	1.20 (0.86, 1.68)	53	81
Upper respiratory infections	1.14 (0.66, 1.95)	21	34
All lower respiratory conditions	1.55 (1.17, 2.05)	85	101
Asthma	1.60 (1.09, 2.35)	47	54
Bronchitis	1.64 (0.98, 2.95)	24	27
Pneumonia	1.84 (0.59, 5.69)	6	6
Ineligible visits for respiratory complaints	4.05 (1.92, 8.52)	22	10

[a]Eligible emergency room visits only (see explanation in test), fire period compared with two pooled reference periods.

Conversely, hospital-based surveys may underestimate an effect if most illnesses associated with exposure are relatively mild or if the exposed population has access to other health care services. The influence of these factors limits the sensitivity of hospital-based surveys in estimating the overall public health impact of acute exposures. Our results therefore probably represent a conservative estimate of overall respiratory morbidity in the smoke-exposed areas. In addition, some of the patients presenting during the fire period were probably not exposed to the smoke since the catchment areas of these hospitals also extend to the east and south of the plume. Thus, the case mix of respiratory complaints during the fire period would have included both exposed and unexposed individuals, resulting in a bias toward the null in the estimates of the ratios of proportions.

All-cause mortality and respiratory-related deaths in the cities of Richmond, San Pablo, and El Sobrante during the fire period and subsequent weeks were well within the usual weekly trends for calendar year 1988. Thus, the fire's impact on acute respiratory morbidity was not reflected in the area's mortality statistics. Nevertheless, smoke exposure may have contributed to the demise of individual patients.

Some, if not most, of the respiratory morbidity associated with exposure to smoke from the warehouse fire might have been prevented by appropriate interventions—for example, official advisories to persons with preexisting respiratory disease, establishment of a shelter in a part of the county unaffected by the smoke, or possibly more aggressive efforts to extinguish the fire. The Richmond–San Pablo area contains a large oil refinery and other chemical production and storage facilities, and local authorities' emergency planning has focused almost exclusively on responses to inadvertent toxic gas releases. Had the fire occurred in a chemical storage facility (as opposed to a supermarket warehouse), a more vigorous response to protect public health, presumably including evacuation, would have been triggered. In situations in which prolonged general population exposure is predictable (as was the case here), organized protective measures should be undertaken expeditiously to prevent acute respiratory morbidity, particularly among persons with preexisting disease. □

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