Special Article

SURVEILLANCE AND PREVENTION OF RESIDENTIAL-FIRE INJURIES

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ABSTRACT

Background The majority of severe and fatal burn injuries result from residential fires. We studied the effectiveness of a smoke-alarm–giveaway program in the prevention of burn injuries in an area with a high rate of such injuries.

Methods We collected data on burn injuries in Oklahoma City from September 1987 through April 1990. The target area for the intervention was an area of 24 square miles (62 km^2) with the highest rate of injuries related to residential fires in the city. We distributed smoke alarms door to door in the target area and then surveyed alarm use and function in a sample of the homes that had received an alarm. We also calculated the rates of fire injury per 100,000 population and per 100 fires for both the target area and the rest of the city before and after the smoke-alarm giveaway.

Results Before the intervention the rate of burn injuries per 100,000 population was 4.2 times higher in the target area than in the rest of Oklahoma City. An initial survey indicated that 11,881 of the 34,945 homes in the target area (34 percent) did not have smoke alarms. A total of 10,100 smoke alarms were distributed to 9291 homes; 45 percent were functioning four years later. The annualized fire-injury rates declined by 80 percent in the target area during the four years after the intervention (from 15.3 to 3.1 per 100,000 population), as compared with a small increase in the rest of the city (from 3.6 to 3.9 per 100,000 population). There was also a 74 percent decline in the target area in the injury rate per 100 fires (from 5.0 to 1.3; rate ratio, 0.3; 95 percent confidence interval, 0.1 to 0.6), as compared with a small increase in the rest of the city.

Conclusions A targeted intervention involving a smoke-alarm–giveaway program can reduce the incidence of injuries from residential fires. (N Engl J Med 1996;335:27-31.)

BURNS are the fourth leading cause of death from unintentional injury in the United States and result in 1.4 million injuries each year.[1,2] Residential fires cause over 75 percent of all deaths from fires and burns.[3-6] The southern part of the United States, including Oklahoma, has the highest regional rate of death from fires (2.5 deaths per 100,000 population)[3,4,7]; this high rate may be due to rural poverty, a lower prevalence of smoke alarms, and greater use of portable heating equipment.[2,8,9] Although the absence of functional smoke alarms in residential dwellings is a risk factor for subsequent injury or death,[6,10,11] surveillance data have not been used to evaluate whether a program to increase the prevalence of smoke alarms in high-risk populations would reduce fire-related morbidity and mortality.

The Oklahoma State Department of Health made burn injuries resulting in hospitalization or death a reportable condition and began active surveillance in September 1987. The purpose of the surveillance system was to guide the development and evaluation of prevention efforts by defining groups at potentially high risk for burn injuries and the circumstances resulting in such injury. The surveillance data identified a target area in south central Oklahoma City with a high rate of injuries related to residential fires. This study describes the use of surveillance, first to identify the need for a community-based intervention (a large-scale smoke-alarm–giveaway program) and then to measure the efficacy of the intervention in reducing residential-fire–related morbidity and mortality in a high-risk population.

METHODS

Surveillance

Surveillance of fire-related injuries resulting in hospitalization in the Oklahoma City Standard Metropolitan Statistical Area

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(all hospitals included) was conducted from September 1, 1987, through April 30, 1994. A case was defined as a burn or smoke-inhalation injury (*International Classification of Diseases, 9th Rev ision, Clinical Modification,* codes 940.0 to 949.9 or 987.9) in any person who died or was hospitalized. Fatal injuries were identified weekly from records of the Office of the Chief Medical Examiner. A case of residential-fire–related injury was defined as a burn or smoke-inhalation injury caused by a fire in an occupied dwelling resulting in the hospitalization or death of a resident; no other causes of injury (e.g., blunt trauma or falls) were included. For each case a standard form was completed with the use of a combination of medical-record review, interviews with patients and their families, and interviews with fire-department employees; the epidemiologic data collected comprised demographic and medical information, including contributing factors (i.e., alcohol use and physical or mental impairment), and the smoke-alarm status of the residence. Completeness of the reporting of cases was validated by comparison of data from hospital discharge records, the fire department, the medical examiner, vital-statistics files, and newspaper clippings.

The rates of residential-fire–related injuries were calculated per 100,000 population (the number of cases as described above ÷ the 1990 U.S. Census population × 100,000) and per 100 fires (the number of cases ÷ the number of fires in occupied dwellings according to the Oklahoma City Fire Department × 100). This led to the identification of the area of Oklahoma City with the highest rate of fire-related injuries and death. Although the true prevalence of smoke alarms in the target area was unknown, data from the Oklahoma City Fire Department suggested that it was considerably lower in the target area than in the other residential areas of Oklahoma City.

Implementation of the Program

According to the 1990 U.S. Census, Oklahoma City covered 621 square miles (1608 km^2) and had a total of 444,719 persons residing in 213,607 dwellings. The target area was a 24-square-mile (62-km^2) section near the middle of the city, where 16 percent (73,301 persons) of the total population resided in 16 percent (34,945) of the dwellings (single- or multiple-family dwellings, excluding apartments). The surveillance data indicated that 47 percent of the injuries resulted from fires started by young children playing with fire ("fire play"), 17 percent from fires started by cigarettes or smoking, 13 percent from fires caused by flammable liquids, 10 percent from fires caused by a heating device, and 13 percent from fires with other or unknown causes. This distribution varied considerably from that in the rest of the city, where injuries most often resulted from fires associated with heating devices (42 percent), followed by cooking (14 percent), cigarettes or smoking (11 percent), fire play (8 percent), electricity and flammable liquids (6 percent each), and other or unknown causes (14 percent).

To determine how many smoke alarms were needed in the target area, we estimated the prevalence of smoke alarms using information obtained by uniformed firefighters during on-site interviews of a random sample of 5 percent of the homes (n=1615). At each home the firefighters requested information on the presence and functional status of a smoke alarm and confirmed the status of the alarm by inspecting it. To estimate the number of homes without a smoke alarm, we applied the prevalence rates found in the survey to the 34,945 occupied homes in the area. We estimated the proportion of homes with no alarm that were reached by the intervention by comparing the number of homes that received an alarm during the project with the estimated number of homes with no alarm.

Homes in the target area (comprising four ZIP Codes) that did not have any functioning smoke alarm were eligible for the intervention. The intervention involved a coalition of community agencies and volunteers who distributed alarms door to door in the target area between May and November 1990. Any resident who requested an alarm could have one installed. All the residents who received an alarm also received educational materials regarding the installation and maintenance of the smoke alarms, prevention of the leading causes of fires, and escape from fires. They also signed a statement agreeing to allow program representatives to inspect the alarm at a later date.

Program Evaluation

To determine the effectiveness of the project in reducing morbidity and mortality, we calculated two injury rates for the target area as well as for the rest of Oklahoma City: the number of fire-related injuries per 100,000 population and the number per 100 residential fires. We also calculated the rate of residential fires per 1000 homes in the target area and the rest of the city; the numerator was the number of fires that occurred in occupied dwellings according to the Oklahoma City Fire Department, and the denominator was the number of occupied homes according to the 1990 U.S. Census.

To assess whether the distributed alarms were installed, maintained, and functioning properly, firefighters conducted on-site alarm inspections at a random sample of participants' homes 3, 12, and 48 months after the initial distribution.

We used Epi Info software for data analysis and calculations of rate ratios.[12,13] We calculated incidence-density ratios using rates before and after the intervention with person-time denominators (comparing the number of cases occurring per unit of population-time — i.e., the number of person-months at risk) and confidence intervals according to the method of Kleinbaum et al.[14]

RESULTS

Surveillance

During the 32-month period from September 1987 to April 1990, a total of 66 persons in Oklahoma City were injured in 46 residential fires (annual rate, 5.6 per 100,000 population); 34 (52 percent) died. The ratio of injuries per fire was similar for the target area (1.2:1) and the rest of the city (1.4:1). Cross-referencing of discharge data from all hospitals, the records of the Oklahoma Department of Vital Statistics, the Office of the Chief Medical Examiner, and the Oklahoma City Fire Department, and newspaper clippings revealed that all injuries meeting the case definition were reported. When the cases were mapped according to the location of the fire, 30 (45 percent) occurred in the target area (Fig. 1), where only 16 percent (73,301 people) of the population lived (annual rate, 15.3 per 100,000 population, as compared with 3.6 per 100,000 in the rest of Oklahoma City; rate ratio, 4.2; 95 percent confidence interval, 2.6 to 6.9). The rate in the target area was 2.6 times higher than that in the rest of Oklahoma City (5.0 vs. 1.9 injuries per 100 residential fires; rate ratio, 2.6; 95 percent confidence interval, 1.6 to 4.5). In the target area, only 4 of the 30 fatal and nonfatal injuries (13 percent) occurred in homes with functioning smoke alarms.

Census data revealed that the target area, as compared with the rest of Oklahoma City, had a lower median household income, lower property values, and a poorer quality of housing (data not shown). The number of persons per occupied dwelling was 2.1 in both the target area and the rest of the city.

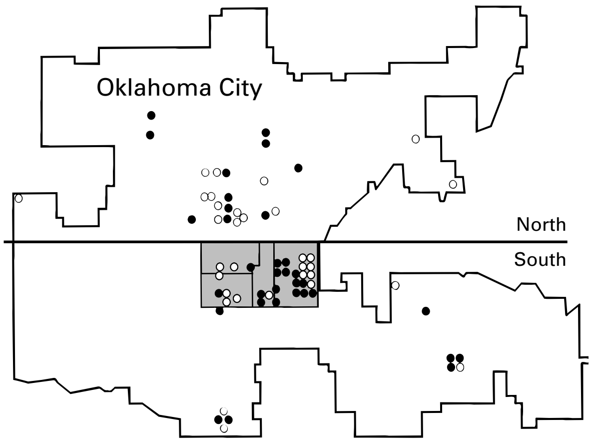

Figure 1. Map of Oklahoma City Showing the Locations of Residential Fires Causing Injury (○) or Death (●) from September 1987 to April 1990, before the Smoke-Alarm–Giveaway Program Was Initiated.

The area targeted for the subsequent intervention consisted of the four ZIP Code areas (shaded area) of the city in which 45 percent of the fires had occurred.

Implementation of the Program

Among the 1615 of 34,945 target-area homes visited by firefighters in the first home survey, 1413 (87 percent) participated. Using data gathered in this home evaluation, we estimated that 66 percent of the households in the target area had smoke alarms and that 11,881 homes had no smoke alarms.

Between May and November 1990, a total of 10,100 smoke alarms were distributed to 9291 homes in the target area; thus, 78 percent of the estimated 11,881 homes without alarms received an alarm. Program representatives installed 917 of the alarms (9 percent).

Program Evaluation

During the four years after the intervention (May 1990 to April 1994), the annualized injury rate per 100,000 population in the target area decreased 80 percent (from 15.3 to 3.1; incidence-density ratio, 0.2; 95 percent confidence interval, 0.1 to 0.4), as compared with a slight increase of 8 percent in the rest of the city (from 3.6 to 3.9 per 100,000 population; incidence-density ratio, 1.1; 95 percent confidence interval, 0.7 to 1.7) (Table 1).

Likewise, the injury rate per 100 residential fires decreased 74 percent in the target area, from 5.0 to 1.3 (rate ratio, 0.3; 95 percent confidence interval, 0.1 to 0.6), whereas in the rest of Oklahoma City the rate increased 32 percent, from 1.9 to 2.5 (rate ratio, 1.3; 95 percent confidence interval, 0.9 to 2.0). The case fatality rate in the target area decreased from 53 percent to 33 percent, while in the rest of the city it decreased from 50 percent to 41 percent; neither of these reductions was statistically significant. In the target area, none of the nine fires resulting in injury after the intervention were caused by fire play (the leading cause before the intervention).

The annual rate of fires reported per 1000 homes continued to be higher in the target area than in the rest of Oklahoma City during the four years after smoke-alarm distribution, although the rate declined in both areas. In the target area, the rate decreased 25 percent, from 6.4 to 4.8 fires per 1000 homes per year after the intervention; in the rest of the city the rate decreased 18 percent, from 3.9 to 3.2 fires per 1000 homes per year after the intervention.

TABLE 1. RATES OF INJURIES RELATED TO RESIDENTIAL FIRES BEFORE AND AFTER THE IMPLEMENTATION OF A SMOKE-ALARM–GIVEAWAY PROGRAM IN THE TARGET AREA AND THE REST OF OKLAHOMA CITY, SEPTEMBER 1987 TO APRIL 1994.

PERIOD*	TARGET AREA				REST OF CITY			
	NO. OF FATAL INJURIES/ TOTAL INJURIES	NO. OF FIRES	ANNUALIZED INJURY RATE/100,000 POPULATION	INJURY RATE/ 100 RESIDENTIAL FIRES	NO. OF FATAL INJURIES/ TOTAL INJURIES	NO. OF FIRES	ANNUALIZED INJURY RATE/100,000 POPULATION	INJURY RATE/ 100 RESIDENTIAL FIRES
Before the smoke-alarm program								
9/87–12/88	11/16	326	16.4	4.9	13/21	906	4.2	2.3
1/89–4/90	5/14	272	14.3	5.1	5/15	942	3.0	1.6
Total (9/87–4/90)	16/30	598	15.3	5.0	18/36	1848	3.6	1.9
After the smoke-alarm program								
5/90–8/91	0/3	237	3.1	1.3	5/15	858	3.0	1.7
9/91–12/92	1/1	183	1.0	0.5	9/20	674	4.0	3.0
1/93–4/94	2/5	249	5.1	2.0	10/23	747	4.6	3.1
Total (5/90–4/94)	3/9	669	3.1	1.3	24/58	2279	3.9	2.5
Incidence-density ratio (95% confidence interval)†			0.2 (0.1–0.4)				1.1 (0.7–1.7)	

*Equal intervals of 16 months are shown for comparison purposes.

†The incidence-density ratio compares the number of cases occurring per person-months at risk in each group before and after the intervention.

To determine whether the alarms were properly installed and maintained, 3 months after the program began firefighters visited a random sample of 9 percent of the 9291 homes (875) that received an alarm; they visited a random sample of 60 percent of homes (5617) after 12 months and 8 percent of homes (749) after 48 months. The first two surveys revealed that the alarms were properly installed and functioning in over 50 percent of the homes inspected (Table 2). During the last inspection, the proportion of occupants who had removed the alarm battery or who had moved and taken the alarm with them was higher than in the first two inspections; nevertheless, 45 percent of the alarms distributed during the program were still functioning four years later. During the four years, 182 homes that received an alarm in the target area reported fires to the fire department; no injuries were associated with these fires.

DISCUSSION

Surveillance data are the foundation of the public health approach to the prevention of diseases and injuries[15,16]; these data are frequently used to conduct epidemiologic studies and to identify high-risk populations, activities, or behavior that prevention programs could target. Although several studies identified populations at high risk for injury or death from fire, high-risk behavior (including the lack of smoke-alarm use), and fire sources that could be targeted in prevention programs,[10,17-21] there are few reports on the implementation and evaluation of a program aimed at reducing fire-related injuries.[22,23] Although smoke alarms have been proved to be effective in reducing the incidence of injuries and death from residential fires (especially fires that occur when occupants are sleeping),[11,24] we are not aware of any previous reports on the efficacy of large-scale smoke-alarm–giveaway programs.

Table 2. Functional Status of Smoke Alarms 3, 12, and 48 Months after the Smoke-Alarm–Giveaway Program.*

Smoke-Alarm Status	3 Months (N=875)	12 Months (N=5617)	48 Months (N=749)
		percent	
Alarm properly installed and functioning (95% confidence interval)	61 (58–64)	51 (50–52)	45 (41–49)
Alarm not installed	20	6	4
Alarm improperly installed	4	2	1
Alarm or battery not functioning	2	5	7
Batteries removed from alarm	2	10	19
Occupant no longer had the alarm	7	14	9
Alarm removed from house when occupant moved	4	11	15

*For each period, the number given is the number of homes included in the random sample of homes that participated in the smoke-alarm–giveaway program. Because of rounding, not all percentages total 100.

In our study, such a program reduced the incidence of fire-related injuries and deaths. The program was based on prospective, ongoing surveillance, which allowed us to focus on an area with a high rate of injuries related to residential fires and a low prevalence of smoke alarms. These data are consistent with the idea that homes that are most likely to burn are those that are least likely to have functioning smoke alarms.[17,25] The 80 percent decline in the rate of injuries in the target area after the intervention was surprising and cannot be explained on the basis of the smoke-alarm–giveaway program alone. Part of the decline in injuries may have been due to a 25 percent decrease in the number of fires per 1000 homes per year after the intervention in the target area. Educational efforts, increased awareness of the importance and prevention of the most common causes of fires in the home, and publicity about the program probably also contributed to the decline in injuries, including the decline in fire-play–related injuries. In addition, the relatively small number of injuries during this study period could have accentuated the decline in injury rates.

Ecologic studies such as this have limitations, including the unavailability of data necessary to control for confounding variables.[26] We think it is unlikely that confounders such as changes in the population prevalence of smoking or drinking or changes in weather conditions were present only in the target area and thus caused or substantially contributed to these results; there were no legislative changes directed at such potential confounders in Oklahoma City during the study period.

Because we used surveillance data to pick the area of the city with the highest rate of injury from residential fires and because of the limited period of observation, some of the decrease in the rates of fire-related injuries may have been a result of regression to the mean.[27] This phenomenon operates in such a way that for any intervention, given a specific level of program efficacy (in this case unknown), the observed effect will be higher if the base-line incidence has fluctuated by chance above its long-term average. In this instance, by picking an area of the city that had the highest rate of fire-related injuries, we would expect the rate to be reduced in subsequent years, even without an intervention. However, we believe that this phenomenon had a minor effect on our results, for several reasons. We analyzed nearly three years of data on the incidence of injury before the intervention. The sudden, marked decline in the injury rate coincided with the implementation of the intervention and persisted for at least four years. We analyzed the number of injuries per 100 residential fires as well as per population, which should minimize any potential bias introduced by the variation in temporal trends, and the number of fires per 1000 homes continued to be higher in the target area even after the intervention. In addition, the type of housing in and demographic characteristics of the target area were well known to be associated with a high risk of residential-fire–related injuries, and it seems unlikely that these factors would have changed rapidly.

The results of this study confirm that the presence of smoke alarms in homes helps prevent fire-related injuries and suggest that programs to increase their use may reduce such injuries, especially in areas identified by ongoing surveillance as having high rates of fires. The use of hard-wired smoke detectors or smoke alarms with lithium batteries (estimated to last 10 years) might lead to even greater benefit as a result of the increased longevity of such products. Interventions that target areas with high rates of fires may be especially efficient ways to lower the incidence of injuries and deaths from residential fires.

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