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ORIGINAL ARTICLES

Urban residential fire and flame injuries: a population based study

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Abstract
***Background*—Fires are a leading cause of death, but non-fatal injuries from residential fires have not been well characterised.**
***Methods*—To identify residential fire injuries that resulted in an emergency department visit, hospitalisation, or death, computerised databases from emergency departments, hospitals, ambulance and helicopter services, the fire department, and the health department, and paper records from the local coroner and fire stations were screened in a deprived urban area between June 1996 and May 1997.**
***Result*—There were 131 fire related injuries, primarily smoke inhalation (76%), an incidence of 36 (95% confidence interval (CI) 30 to 42)/100 000 person years. Forty one patients (32%) were hospitalised (11 (95% CI 8 to 15)/100 000 person years) and three people (2%) died (0.8 (95% CI 0.2 to 2.4)/100 000 person years). Injury rates were highest in those 0–4 (68 (95% CI 39 to 112)/100 000 person years) and ⩾85 years (90 (95% CI 29 to 213)/100 000 person years). Rates did not vary by sex. Leading causes of injury were unintentional house fires (63%), assault (8%), clothing and nightwear ignition (6%), and controlled fires (for example, gas burners) (4%). Cooking (31%) and smoker's materials (18%) were leading fire sources.**
***Conclusions*—Because of the varied causes of fire and flame injuries, it is likely that diverse interventions, targeted to those at highest risk, that is, the elderly, young children, and the poor, may be required to address this important public health problem.**
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Globally, fires are an important contributor to death and disability.[1] In the United Kingdom, residential fires caused at least 500 deaths and 15 000 injuries in 1998.[2] Many population based epidemiological studies of fire related injuries have focused on burns.[3–8] However, most fire injuries are caused by smoke inhalation and their causes are likely to differ from those of burns. Most other studies of fire injuries have been restricted to hospitalisations or deaths,[9–16] which account for only a small proportion of such injuries. Causes of fire related hospitalisations may differ from those of less serious injuries. For an on-going randomised controlled trial evaluating a smoke alarm giveaway programme to reduce fire related injuries,[17] comprehensive surveillance is being conducted to identify residential fire and flame injuries. With these data, we sought to characterise the burden of fatal and non-fatal injuries resulting from residential fires that require emergency care, in order to develop targets and priorities for intervention.

Methods

STUDY POPULATION

The inner London study area comprises an ethnically and racially diverse, materially deprived, densely housed population of 366 000 (London Research Centre, projection 1, ©1998).

CASE DEFINITION

Fire related injuries included burns, smoke inhalation, or any other injury resulting from a fire (for example, laceration incurred while escaping a burning building) in an occupied dwelling within the study area between 1 June 1996 and 31 May 1997, that resulted in an emergency department visit, hospitalisation, or death. Injuries occurring in residential institutions (for example, nursing homes) and non-residential settings were excluded.

METHODS

Fire related injuries were identified by screening routinely collected data from a variety of sources, including local emergency departments and hospitals, ambulance and helicopter services, the fire department, and local coroner. In five emergency departments, including all three within the study area, computerised databases of emergency visits were searched by diagnostic code (["burns/electrocution", "inhalation/drowning"] or ["burns/scalds", "poisoning", "respiratory conditions"] depending on the database), and diagnostic and presenting complaint texts ("fire", "burn*", "smoke", "inhal*").† The computerised

†The asterisk ("truncation" mark) indicates any or no character after the initial term, for example, burn* would identify burn, burns, burning, burned, etc.

database of the sixth emergency department could be searched only by diagnostic code ("skin/soft tissue burns" or "respiratory disorder"). The seventh emergency department did not have a searchable database. On a monthly basis the research assistant reviewed all presenting complaints on-screen for any cases including "fire", "burns", "smoke", "inhalation", or unspecified respiratory complaints. These searches identified 3808 potentially eligible emergency department visits.

The computerised discharge databases of the seven local hospitals were screened for cases with a relevant external cause or nature of injury†.[18] Using the same codes, we also searched a computerised database of all area residents hospitalised in National Health Service hospitals, which is maintained by the local health department. These searches identified 327 potentially eligible records. Records from hospitals outside Greater London (except those with specialised burn units) were excluded.

The computerised databases of the London Ambulance and Helicopter Emergency Medical Services were searched for any calls within the study area described or coded as a fire, burn, or inhalation. We also examined the London Fire Brigade's computerised register of fire fatalities for deaths within the study area. The fire department does not maintain a complete computerised database of non-fatal incidents. Hence, we screened standardised paper report forms from 14 local fire stations for fires attended in the study area. The handwritten log of the local Coroner's Court was reviewed for deaths caused by "fire", "burn", or "smoke inhalation". We also reviewed any additional records identified by these searches (for example, the ambulance record specified transport to an emergency department but the visit had not previously been identified).

To determine eligibility, we reviewed the records of all potentially relevant cases identified by screening. From the medical notes of eligible cases, a research assistant recorded date, incident address, circumstances, name, age, sex, physical examination, laboratory tests, diagnoses, treatment, disposition, and duration of hospitalisation (counting same day discharges as zero days duration), on a standardised form. No measures of ethnicity or socioeconomic status were available from the data sources. The research assistant also used standardised forms to record data on date, incident address, and circumstances from fire and emergency transport incidents.

All relevant records were entered into a Microsoft Access database. Only the first encounter for each patient event was entered as an incident record. Attempts were made to link records. Fire and transport personnel frequently misspelled names whereas medical records often failed to specify the incident address. Therefore, incidents that matched on date or date plus one day, home or incident address, postcode (first three digits), or surname (first three letters) were provisionally linked. Provisional linkages were manually reviewed to identify true matches, which were then coded to mark the linkage. Once linked, data were cross checked to correct and complete the incident address and postcode, cause of injury, and source of ignition.

When eligibility could not be determined because the medical notes were missing (2% of 3808 records), or the address or cause of injury was not specified in the notes and could not be determined through linkages (approximately 6%), a brief postal survey was sent to the patient. It asked two questions: (1) was the injury caused by a fire or flame? (and if yes, what were the circumstances), and (2) did the injury occur at a home? (and if yes, what was the address).

Where a patient's notes were missing, the case was nevertheless entered in the database if a record of the visit was entered into the computerised administrative databases kept by each hospital and if sufficient information was available from ambulance or fire department records or a patient survey to confirm eligibility.

We included all injuries occurring in the study area, regardless of residency of the patient. Therefore, the correct denominator for incidence rates is the number of residents and non-residents multiplied by the time each spent in the study area during the study period (that is, person time at risk). As we had no way to estimate this, we assumed that the person time that non-residents spent within the study area and hence at risk of incurring an injury was equivalent to the person time that residents spent outside the study area and therefore not at risk. To estimate person time at risk for the one year study, we calculated the total population living in the study area at the study mid-point using mid-year estimates projected from the 1991 census (London Research Centre, projection 1, © 1998).

As a measure of socioeconomic status, the 46 electoral wards in the study area were divided into tertiles by Townsend score.[19] We calculated 95% confidence intervals (CI) for rates using the Poisson distribution. The Great Ormond Street Hospital/Institute of Child Health Research Ethics Committee approved this study.

Results

The surveillance system identified 131 patients meeting the case definition, of whom 129 were seen in the emergency department and two died at the scene of the fire. Of 131 patients, 94 (72%) were identified from emergency department records alone, three (2%) from emergency department records plus patient surveys to confirm eligibility, 12 (9%) from hospital discharge databases, 20 (15%) from

† External cause of injury codes included X00–X09, X76, X97, and Y26, comprising exposure to smoke, fire and flames, whether unintentional, intentional, or of undetermined intent. Nature of injury codes included T20–32, T58, T59, and J68, comprising burns, toxic effects of carbon monoxide or gases, fumes and vapours, and respiratory conditions due to inhalation of chemicals, gases, fumes, and vapours.

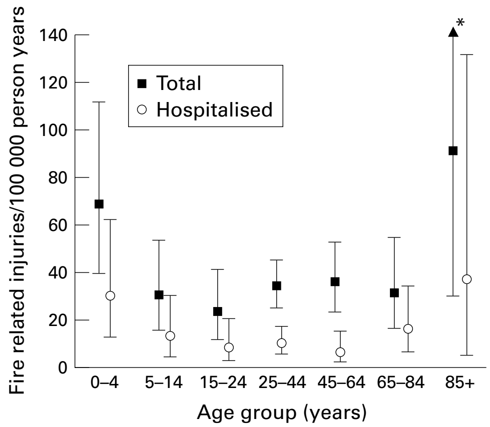

*Figure 1 Total and hospitalisation incidence rates for residential fire and flame injuries, by age group. *Upper 95% CI = 213.0.*

ambulance transport records, and two (2%) from the coroner's log.

Forty one of 131 patients were hospitalised. Hospital discharge records identified 23 (56%) of these, emergency department records identified an additional 14 (34%), and ambulance records found four cases (10%). Of three deaths, two were identified from the coroner's log and one from emergency department records.

INCIDENCE OF FIRE RELATED INJURIES

The total incidence rate of fatal and non-fatal injuries was 36 (95% CI 30 to 42)/100 000 person years. Rates were higher among children and elderly persons (fig 1), but they did not differ by sex. In the least deprived tertile of wards, the incidence rate was 26 (95% CI 17 to 38)/100 000 person years. Among those in the middle and most deprived tertiles, rates were 41 (31 to 53) and 39 (29 to 52)/100 000 person years, respectively.

CIRCUMSTANCES OF INJURY

Unintentional house fires caused most injuries (table 1). The most common ignition sources for fires were cooking (40/131, 31%), cigarettes or lighters (23/131, 18%), electric blankets, appliances or wiring (11/131, 8%), and arson or malicious intent (10/131, 8%).

NATURE OF INJURY

Principal diagnoses were smoke inhalation (89/131, 68%), burns (28/131, 21%), or both (11/131, 8%). Only three patients had other diagnoses, including parental neglect (2) and contusion (1). The 89 patients with smoke inhalation injury alone included 70 of 82 (85%) injured in unintentional house fires, 10 of 12 (83%) exposed to smoke, fire and flames with undetermined intent, and eight of 11 (73%) assaulted with smoke, fire, and flames. Among the 26 patients with other external causes of injury (table 1), 25 (96%) had burns (two with smoke inhalation as well) while only one had isolated smoke inhalation.

Carboxyhaemoglobin was assessed in 36 patients, of whom five (14%) had concentrations ⩾10% (range 1% to 32%). Of 39 burned patients, six (15%) had burns involving >5% total body surface area (range 0.1% to 100%).

DISPOSITION

Sixty two (47%) of 131 patients were discharged to home without follow up and 11 (8%) left before treatment. Outpatient follow up was recommended for 15 patients (11%), all of whom had burns. The median number of outpatient follow up visits was one (range one to seven). Disposition was unknown for one patient (<1%).

Forty one patients (32%) were hospitalised, including four transferred for specialised burn management or hyperbaric oxygen therapy. Children under 15 and adults over 64 years were more likely to be hospitalised (44% and 47%, respectively) than were adults aged 25 to 64 (24%) (fig 1). Among 34 patients with complete records, the median length of stay was four days (range zero to 45). There were three deaths (2%), a rate of 0.8 (0.2 to 2.4)/100 000 person years. A woman aged 36 and a man aged 87 died at the fire scene, while a man aged 82 died from complications of smoke inhalation after 45 days in hospital. Hospitalisation or death was equally likely among patients diagnosed with burns alone (10/28 or 36%), smoke inhalation alone (27/89 or 30%), or both (4/11 or 36%).

Discussion

The incidence of residential fire related injuries resulting in an emergency department visit, hospitalisation or death in a multiethnic, impoverished inner London area was 36/100 000 person years. Most injuries were

Table 1 Numbers and percentages of patients with fire related injuries, and rates of fire related injuries, according to external cause of injury

*Description (code)**	*No (%) patients*	*Rate/100 000 person years (95% CI)*
Uncontrolled fire in building (X00)	82 (63)	22.4 (17.8 to 27.8)
Exposure to smoke, fire and flames, undetermined intent (Y26)	12 (9)	3.3 (1.7 to 5.7)
Intentional assault by smoke, fire, and flames (X97)	11 (8)	3.0 (1.5 to 5.4)
Ignition or melting of nightwear or other clothing and apparel (X05, X06)	8 (6)	2.2 (0.9 to 4.3)
Controlled fire in building (X02)	5 (4)	1.4 (0.4 to 3.2)
Other specified smoke, fire, and flames (X08)	4 (3)	1.1 (0.3 to 2.8)
Intentional self harm by smoke, fire, and flames (X76)	3 (2)	0.8 (0.2 to 2.4)
Contact with hot drinks, food, fats, and cooking oil† (X10)	3 (2)	0.8 (0.2 to 2.4)
Explosion of other materials‡ (W40)	2 (2)	0.5 (0.1 to 2.0)
Ignition of highly flammable material (X04)	1 (1)	0.3 (0.0 to 1.6)
Total	131 (100)	35.8 (29.9 to 42.5)

*Based on World Health Organisation International Classification of Diseases (ICD-10).
† Occurred while moving a flaming chip pan off the stove.
‡ Involved explosion of gas during ignition of gas cooker with match.

caused by exposure to unintentional house fires, but more than one third were attributable to a wide range of other exposures. One third of all injured patients were hospitalised or died, underscoring the seriousness of these injuries. The identification of fire related injuries required a wide range of information sources, with no one source reliably identifying all of them.

Other studies of injuries due to fire have focused on hospitalisations and deaths, and most have reported only on unintentional fire injuries. In Oklahoma City, the total fire related hospitalisation and death rate was 3.6/100 000 in 1987–90,[14] compared with 8.2/100 000 in our study using a similar case definition. In the south eastern United Kingdom, which includes urban, suburban and rural populations,[15] the hospitalisation rate for unintentional fire and flame injuries (X00–X09) was 4.5/100 000 in 1994–95, substantially lower than the estimate from our population of 7.9/100 000. In an urban United Kingdom population of children aged 0–14, the unintentional fire related injury hospitalisation rate in 1989 was 10/100 000 person years,[8] again somewhat lower than the comparable rate of 14/100 000 in our study.

In contrast, in a high risk area of inner Oklahoma City, the fire related hospitalisation and death rate was substantially higher at 15.3/100 000.[14] Among children aged 0–19 in a Native American population, the hospitalisation rate for unintentional fire and flame injury was as high as the rate for that age group in our study (11.7 *v* 10.6/100 000, respectively).[16] Within our study population, those living in areas of greater deprivation appeared to be at greater risk of fire related injuries than did those living in less deprived areas. It has previously been shown that in England and Wales, the risk of death from fire and flame was 16-fold higher among children in social class V compared with social class I, indicating a steep social class gradient in the risk of fire related death.[20] All of these studies, with ours, indicate the important contribution of poverty to the risk of fire related injury, hospitalisation, and death across diverse populations.

Strengths and limitations

We used a comprehensive surveillance system to identify cases. Emergency department surveillance missed 25% of cases seen in the emergency department, while searches of hospital discharge databases failed to identify 44% of hospitalisations and the screening of coroner's records missed one of three deaths. Principal reasons for missed cases were missing or incomplete records, miscoding, or lack of coding. Restricting surveillance to a single data source would have substantially underestimated morbidity and mortality from residential fire injuries. Similar requirements for using combined data sources and modalities have been identified for surveillance of other types of injuries, for example, agricultural injuries.[21]

The true incidence of fire related injuries is, nevertheless, even higher than estimated here, because patients with less serious injuries requiring medical care may elect to see their own physicians. Even serious injuries may have been underestimated because of coding errors and incomplete or missing records. To avoid such underestimates, we searched diagnostic and presenting complaint text as well as diagnostic codes, and screened both external cause and nature of injury codes. We also used multiple data sources, surveyed patients, and linked records from different sources to determine eligibility.

Incidence rates might have been overestimated if the person time that non-residents spent in the study area (and hence "at risk") was greater rather than the person time that residents spent outside the area (that is, not at risk). There is no reason to suspect this, however.

Implications for prevention

Injuries have become an increasingly important contributor to global morbidity and mortality.[1] In the United Kingdom, injuries caused by fire and flame are relatively more serious than many other types of home injuries: 32% of patients with fire related injuries were hospitalised compared with 6% of patients seen in emergency departments for all types of home injuries combined.[22] In addition, fire injuries show the steepest social class gradient among all childhood injuries.[20] Because of their severity and their contribution to health inequalities, and because potentially effective interventions exist,[23 24] fire related injuries should be targeted for prevention efforts.

House fires cause the largest proportion of fire related injuries. Two recent reviews did not identify evidence of a beneficial effect from community, school, or clinic based fire safety education on fire injuries, although clinical counselling does appear to modestly improve smoke alarm ownership.[23 25] Two non-randomised trials suggest that smoke alarm giveaway programs may be effective in reducing fire related injuries,[25] while legislation requiring smoke alarm installation or other fire protection measures is a potential solution implemented in many countries.[26] However, the problem of alarm maintenance (for example, battery replacement), especially among impoverished households,[27] must still be resolved.

Numerous other interventions to prevent fire related injuries have been proposed.[24] Our data support the potential benefits of smoking prevention and cessation programs, given that smokers' materials were the sources of ignition in 18% of fires. Six per cent of injuries resulted from clothing or nightwear catching fire, suggesting that flame retardant clothing may be a beneficial intervention. A large proportion of our population live in older homes which may have substandard electrical wiring, appliances and heating devices, and 8% of injuries were due to electrical failures. Efforts to address electrical systems and appliances, with building codes, regulations, financial incentives for replacement, or other efforts to reduce substandard housing, may be of use in similar populations. Other promising environmental modifications include self extinguishing cigarettes, non-flammable furnishings and building materials, and the wider use of sprinkler systems. In our study, 10% of injuries were intentional. Measures designed to prevent unintentional fires are less likely to prevent such injuries. Clinical and community interventions to address domestic violence and substance abuse and to promote the adequate monitoring and treatment of patients with mental illness may be of value.

Because of the varied causes of fire and flame injuries, it is likely that diverse interventions targeted to those at highest risk, that is, the elderly, families with young children, and the poor, may be required to address this important public health problem.

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