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PAPER

PATHOLOGY/BIOLOGY

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Circumstances of Death and Diagnostic Difficulties in Brushfire Fatalities

ABSTRACT: The deaths of 10 bushfire (brushfire) victims (aged 2–59 years; M/F 1:1) from the files of Forensic Science SA in Adelaide, South Australia, over an 8-year period (January 2002 to December 2009) are reported. Nine of the victims were found in or near motor vehicles. Death was attributed to incineration ($N = 5$), trauma from bushfire-related vehicle crashes ($N = 2$), inhalation of products of combustion with hyperthermia ($N = 1$), inhalation of products of combustion ($N = 1$), and undetermined ($N = 1$). Death scenes covered large areas and involved many victims. Loss of infrastructure and closure of local roads owing to debris limited access and made the finding of bodies difficult. Bodies in such fires may be exposed to the damaging effects of weather and animal predation. Heat damage hindered pathological assessment with resultant delays in identification. Assessment of antemortem injuries and determination of causes of death were also complicated by the condition of some of the bodies.

KEYWORDS: forensic science, bushfires, brushfires, incineration, identification, disaster victim identification

Many parts of Australia have hot, dry summers that predispose to fires in forest or scrub country. These are known locally as bushfires and are often associated with significant property damage and loss of domestic and wild animal life. Bushfire-related deaths have long been a part of life in Australia with 71 deaths in the Black Friday fires in Victoria in 1939, and 62 deaths in the Tasmanian bushfires of 1967 (1). Seventy-five deaths occurred in South Australia and Victoria in the 1983 Ash Wednesday fires (2). In the recent years, it has been suggested that there has been a drying out of the landscape owing to drought, with an increase in the frequency of severe fire weather (3), factors that may predispose to an increased frequency and intensity of fires. Certainly, the scale of the bushfires in Victoria in 2009 that resulted in 173 deaths would be supportive of this. Conditions that predisposed to the conflagration in Victoria, in which more than 100 fires were burning at one stage, included very low humidity (7%), strong northerly winds, and extreme temperatures of up to 49°C (120°F) (4). Several years earlier, in 2003, fires in Victoria engulfed an area equivalent to the entire country of Germany (5).

The problem of bushfires is not, of course, restricted to Australia, with 453 deaths occurring in fires in Cloquet, Minnesota in 1918, 230 deaths in the Landes region of France in 1949, 213 deaths in Greater Hinggan, China in 1987, and 240 deaths in fires in Indonesia in 1997 (1). More recently, extensive fires have occurred in Califonia (6,7). Dry winter conditions have been associated with forest fires in Mexico, with dry forests predisposing to fires in nearby Cuba, the Bahamas, and the Dominican Republic (8,9). Warmer drier summers in England have been linked to wildfires in moorlands areas (10), and it has been suggested that increase in global temperatures may result in an "unprecedentedly fire-prone environment" (11). Over the past several years, bushfires in various parts of South Australia have also resulted in the loss of human lives, although on a smaller scale. The details of these cases and diagnostic problems that arose in their evaluation are presented.

Materials and Methods

The files of Forensic Science SA in Adelaide, South Australia, were examined over an 8-year period from January 2002 to December 2009 for cases where deaths had been attributed to bushfires. Forensic Science SA provides autopsy services to the State Coroner for the State of South Australia, Australia, which has a population of approximately 1.6 million people. The majority (>95%) of the state's coronial autopsies are performed at the center. Police and coronial files were reviewed, the autopsy findings were examined, and the details of the cases were summarized.

Results

A total of 10 cases were found involving two separate bushfires; one on the Eyre Penisula in 2005 where nine people died and the second on Kangaroo Island in 2007 where there was one victim. The victims were aged between 2 and 59 years with a male-to-female ratio of 1:1. Nine of the victims were found in or near motor vehicles.

Case 1

The markedly charred body of a 22-year-old man was found behind the front seat of a burnt out truck. The body weight was

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only 42 kg, with loss of the face, neck, and limbs and charring of internal organs. Toxicology revealed a carboxyhemoglobin level of 17% with a small amount of alcohol, most likely due to putrefactive changes. There were no common drugs. Death was attributed to incineration. Also found with the victim was a cell phone that he had used to call and send text messages describing the fire.

Case 2

The putrefactive body of a 57-year-old woman was found in a bathtub of water in a burnt out house. The feet were charred and soot was identified in the upper airways. Toxicology revealed a carboxyhemoglobin level of 27% with a small amount of alcohol, most likely due to putrefactive changes. There were no common drugs. Death was attributed to the combined effects of inhalation of products of combustion, and hyperthermia.

Case 3

The charred body of a 2-year-old boy was found in a burnt out vehicle with the victims in Cases 4 and 5, and the body of a pet dog. There was no evidence of a vehicle crash. Autopsy revealed extensive burning with soot within the upper airways. Carboxyhemoglobin analysis was not possible owing to dessication of tissues. Death was attributed to incineration.

Case 4

The charred body of a 3-year-old girl was found in a burnt out vehicle with the victims in Cases 3 and 5. Autopsy revealed extensive burning with soot within the upper airways. Toxicology revealed a carboxyhemoglobin level of 7% with no cyanide, alcohol, or common drugs. Death was attributed to incineration.

Case 5

The charred body of a 59-year-old woman was found in a burnt out vehicle with the victims in Cases 3 and 4. Autopsy revealed extensive burning. The body weight was only 22 kg, with loss of the limbs and charring of internal organs. Soot was identified histologically within the smaller airways. Toxicology revealed a carboxyhemoglobin level of 61% with a potentially lethal level of cyanide of 1.6 mg/L. A therapeutic level of codeine was present, but no alcohol or other common drugs. Death was attributed to inhalation of products of combustion.

Case 6

The charred body of a 30-year-old man was found in the back of a burnt out utility truck. Autopsy revealed severe charring of all areas with soot in the upper airway. Toxicology revealed a carboxyhemoglobin level of 7% with no cyanide, alcohol, or common drugs. Death was attributed to incineration.

Case 7

The charred and putrefied body of a 54-year-old man was found on a road near the burnt out utility truck in Case 6. Autopsy revealed severe charring of all areas with no soot in the upper airway. Toxicology revealed a carboxyhemoglobin level of 7% with a small amount of alcohol, most likely due to putrefactive changes. There was no cyanide or common drugs. Death was attributed to incineration.

Case 8

The severely charred remains of an 11-year-old girl were found in the rear passenger's seat of a burnt out vehicle that had struck a tree at high speed, with the victims in Cases 9 and 10. Autopsy revealed severe charring of all areas with a small amount of soot in the upper airway. Toxicology revealed a carboxyhemoglobin level of 7% with no cyanide or common drugs. The cause of death was undetermined given that lethal trauma from the vehicle collision could not be excluded.

Case 9

The severely charred body of a 13-year-old boy was found in the front passenger's seat of a burnt out vehicle that had struck a tree with the victims in Cases 8 and 10. Autopsy revealed severe charring with a small amount of soot in the upper airway. There were, however, antemortem fractures discernable of the base of skull and both legs. Toxicology revealed a carboxyhemoglobin level of 4% with no cyanide or common drugs. Death was attributed to multiple injuries followed by incineration of the body.

Case 10

The severely charred body of a 33-year-old woman was found in the driver's seat of a burnt out vehicle that had struck a tree with the victims in Cases 8 and 9. Autopsy revealed severe charring with no soot in the upper airway. There were full thickness lacerations of the heart. Toxicology revealed a carboxyhemoglobin level of 4% with no cyanide or alcohol. Therapeutic levels of paracetamol and codeine were present. Death was attributed to cardiac rupture from blunt chest trauma followed by incineration of the body.

The case details are summarized in Table 1.

Discussion

Bushfire deaths raise a number of issues that are not normally encountered in smaller more localized fires. The death scene may cover many hundreds of square miles and involve a large number of victims necessitating the instigation of formal large-scale disaster victim identification (DVI) processes (12). Loss of infrastructure and closure of local roads owing to debris may make access to death scenes difficult, and finding badly burnt bodies among the wreckage of buildings or scattered outside may not be easy. The outdoor location of some of the deaths may expose bodies to the damaging effects of weather and animal predation (13). The destructive nature of intense heat also makes the pathological assessment of bodies complicated, with difficulties in identification, assessment of possible antemortem injuries, and determination of the exact causes of death (Table 2).

Bushfires may also involve major cities with, for example, fires in Australia in 2003 moving into Canberra, the national capital, destroying 503 homes and causing four deaths (14). Sydney in New South Wales has also experienced bushfires in peripheral suburbs (15). In addition to directly causing death and injury, bushfires have also been associated with an increase in hospital admissions owing to respiratory morbidity from the inhalation of soot and particle debris (7,15) and to an exacerbation of psychiatric disease (16).

Deaths in fire situations result from a variety of causes and mechanisms and these are summarized in Table 3. Generally, if a victim is alive at the time of exposure to a house fire, death results

TABLE 1—*Summary of features of 10 cases of bushfire-related fatalities in South Australia.*

	Age (Years)	Sex	Burns	Injuries	Soot in Airway	Blood CO	Organic Disease	Cause of Death	Identification	Vehicle Related
1	22	M	++	ND	ND	17	ND	Incineration	Circumstantial	Yes
2	57	F	+	−	+	27	−	Inhalation of POC + hyperthermia	Dental	No
3	2	M	++	ND	+	N/A	ND	Incineration	DNA	Yes
4	3	F	++	ND	+	7	ND	Incineration	DNA	Yes
5	59	F	++	ND	+	61	ND	Inhalation of POC	Dental	Yes
6	30	M	++	−	+	7	−	Incineration	DNA	Yes
7	54	M	+	−	−	7	−	Incineration	Dental + DNA	Yes
8	11	F	++	ND	+	7	−	Undetermined	DNA	Yes
9	13	M	+	+	+/−	4	−	Multiple injuries	DNA	Yes
10	33	F	++	+?	−	4	−	Cardiac rupture	DNA	Yes

M, male; F, female; CO, carbon monoxide; ND, not determined; N/A, not available; POC, products of combustion.

TABLE 2—*Problems associated with determining the cause, mechanism and manner of death in bushfire-related fatalities.*

Destruction of and damage to body by fire
Missing parts and organs
Extensive postmortem artifacts
Variability of carbon monoxide levels
Possible contribution of preexisting natural disease
Outdoor locations
Putrefactive changes
Animal predation
Loss of body parts
Possibility of other lethal trauma
Vehicle crash
Building collapse
Falling debris from trees

TABLE 3—*Causes and mechanism of death in bushfire-related fatalities.*

Inhalation of products of combustion
Carbon monoxide
Other toxins, for example, cyanide
Asphyxia from oxygen deprivation
Thermal injuries
Airway
Elsewhere
Exacerbation of natural diseases
Ischemic heart disease
Other
Trauma
Directly from the fire
Owing to activities associated with attempted escape

from carbon monoxide toxicity. Carbon monoxide causes death from asphyxia by directly competing with oxygen for hemoglobin, having a 250–300 times greater affinity for the hemoglobin molecule than oxygen. Thus, oxygen is soon displaced, resulting in deprivation of oxygen at the cellular level. In addition, carbon monoxide is thought to be directly toxic to cells. Levels of carbon monoxide that may be clinically significant or lethal, vary, with lower levels causing death in infants and young children, and in the elderly. In a healthy adult, blood carboxyhemoglobin levels of more than 50–60% are usually considered lethal (17). In the present series, only one victim had a lethal level of carboxyhemoglobin, and testing for cyanide was also negative in the other cases indicating that there had not been exposure to burning plastics. The absence of carboxyhemoglobin has been previously noted in bushfire deaths (2) and suggests that most deaths are related to other mechanisms such as incineration, heat exposure, or asphyxia from rapid consumption of oxygen by the advancing fire front. Oxygen depletion may explain why carboxyhemoglobin levels may be lower than expected. Those exposed to fires may also suffer exacerbations of underlying cardiovascular or respiratory disease (6,18).

Direct thermal injury may cause death, and this may be in the form of heat injury to the upper airway causing laryngeal spasm, reflex cardiac arrest, or massive edema, and swelling of tissues thus preventing air intake. Bushfires may be associated with extreme heat, and it has been shown that temperatures of 300°C (572°F) may be reached in the center of a 9-m diameter clearing surrounded by fire with flame heights of 25 m. Such temperatures cause severe facial and upper airway burns within minutes. Other problems associated with heat exposure include dehydration and heat exhaustion, particularly among fire fighters (3). Scalding may occur in those who seek refuge in rainwater tanks.

One of the striking situations that was encountered in the current study involved the use of motor vehicles. Ninety percent of those who had died were found in or near vehicles with three clusters, two involving an adult with young children, and the other, two men who were traveling together. In two groups, fire had overtaken the vehicle and the victims had either incinerated or died from inhalation of products of combustion. In the remaining group, a crash had occurred presumably associated with the urgency of the situation and the very poor visibility. In this case, at least two of the victims had died of trauma associated with the collision; however, determining the exact cause of death in victims who have been involved in vehicle crashes followed by incineration may not be possible, as occurred in Case 8. While vehicles may provide some protection from heat and flames, they may lead to death if they ignite and are not abandoned. Young children in vehicles may also be at increased risk as they tend to practice avoidance of flames, rather than escape (19). Considerable debate has occurred in Australia regarding the advisability or not of leaving a fire front; however, on occasion, no situation will be safe in the face of a rapidly advancing intense fire.

The identification of incinerated remains is often difficult and in the current cases DNA testing proved useful in seven cases, with dental identification being completed in three; in one victim (Case 7), both DNA and dental identifications were undertaken. In Case 1, circumstantial identification was accepted given that the victim was known to have been driving in the incinerated vehicle, that he had made phone calls and sent text messages on the cell phone that was found next to the body, and that there was only one fatality in this particular bushfire.

The investigation of bushfire deaths involves the integrated activity of a wide variety of agencies in a formal DVI setting so that victims' remains can be identified, secured, and preserved for subsequent dental, anthropological, and pathological evaluation. A central command post needs to be established in a secure area with full access to facilities required to run a morgue. Coordination of such activities is usually undertaken by police, with or without armed forces assistance.

The fragility of carbonized teeth and bones means that good quality photographs should be taken at the scene (20) with reinforcing of teeth with fast setting adhesive, if required, prior to any attempt at removal. The possibility of an inflicted traumatic death or death attributed to other forms of trauma, as in Cases 8, 9, and 10, should be considered, as should the possibility of underlying natural disease. Toxicological evaluation is essential, both for carbon monoxide and cyanide, but also to check for alcohol or drugs that may have adversely affected behavior and promoted risk taking.

Bushfire fatalities are often difficult to deal with logistically and diagnostically. Issues arise concerning causes of death and identification and may result in cases taking some time to finalize. Despite the pressure for fast identifications, however, a measured approach to such cases is required to maximize the chances for positive identifications and to enable subsequent appropriate medico-legal evaluation of the circumstances of the fires and deaths.

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