The American Journal of Forensic Medicine and Pathology 22(4):374–382, 2001.

Environmental Hyperthermic Infant and Early Childhood Death

Circumstances, Pathologic Changes, and Manner of Death

Henry F. Krous, M.D., Julie M. Nadeau, B.A., Richard I. Fukumoto, M.D., Brian D. Blackbourne, M.D., and Roger W. Byard, M.D.

Infant and early childhood death caused by environmental hyperthermia (fatal heat stroke) is a rare event, typically occurring in vehicles or beds. The aims of this study were to describe the demographics, circumstances, pathology, and manner of death in infants and young children who died of environmental hyperthermia and to compare these cases with those reported in the literature. Scene investigation, autopsy reports, and the microscopic slides of cases from three jurisdictions were reviewed. The subjects in 10 identified cases ranged in age from 53 days to 9 years. Eight were discovered in vehicles and 2 in beds. When the authors' cases were grouped with reported cases, the profile of those in vehicles differed from those in beds. The former were older, were exposed to rapidly reached higher temperatures, and often had more severe skin damage. The latter were mostly infants and were exposed to lower environmental temperatures. Hepatocellular necrosis and disseminated intravascular coagulation were reported in victims who survived at least 6 hours after the hyperthermic exposure. The consistent postmortem finding among nearly all victims was intrathoracic petechiae, suggesting terminal gasping in an attempt at autoresuscitation before death. The manner of death was either accident or homicide. Recommendations for the scene investigation are made.

Key Words: Hyperthermia—Heat stroke—Sudden infant death—Pathology—Petechiae—Child neglect—Manner of death—Burns.

Infant and early childhood death after exposure to environmental hyperthermia (fatal heat stroke) is a rare but recognized event that typically occurs in motor vehicles or beds (1–13). Infants and young children left unattended in motor vehicles are at risk for heat stroke and death because intravehicular temperatures can increase quickly to lethal levels, especially when the vehicles are parked in direct sunlight (1,6,14,15). Hyperthermic illness and death in a bed is often the result of a combination of several factors (3,4,7,8,12). The manner of death has been reported as homicide in some of these cases (5), but most are likely accidents (3,8).

The postmortem findings vary and depend on the duration of survival after hyperthermic exposure (9). They include intrathoracic, cutaneous, and conjunctival petechiae; pulmonary and cerebral edema; visceral cellular degeneration and necrosis; and disseminated intravascular coagulation (DIC) (9,16–19).

Despite the appearance of anecdotal reports (1–13), systematic reviews of the circumstances, pathology, and manner of death in a series of fatal pediatric cases are lacking. One oft-cited study of childhood heat illness focused primarily on the clinical features emphasizing its association with underlying diseases and acute illnesses (20). Therefore, the aims of the current study were to describe the circumstances, pathology, and manner of death in a series of infants and young children without major medical problems who died as a result of exposure to environmental hyperthermia, and to compare the findings in these cases with those reported in the literature.

MATERIALS AND METHODS

Cases were identified after a search of the files of the Office of the San Diego County Medical Examiner, the Office of the Orange County Coroner in California, and the Forensic Science Center in Adelaide, South Australia. The reports of the scene investigation and postmor-

Manuscript received April 24, 2001; accepted July 13, 2001.

From Children's Hospital–San Diego (H.F.K., J.M.N.); University of California, San Diego School of Medicine (H.F.K.); Office of the Coroner, Orange County, California (R.I.F.); Office of the Medical Examiner, County of San Diego, San Diego, (B.D.B.) California; and Forensic Science Centre and University of Adelaide, Adelaide, South Australia (R.W.B.).

Address correspondence and reprint requests to Henry F. Krous, M.D., Children's Hospital–San Diego, 3020 Children's Way, MC5007, San Diego, CA 92123, U.S.A.; E-mail: hkrous@chsd.org

tem examination as well as the microscopic slides of each case were reviewed and analyzed.

RESULTS

Ten cases were identified. The salient features are provided in Table 1. The subjects ranged in age from 53 days to 3191 days (9 years); 7 were male; 8 were white, 1 was Hispanic, and 1 was black. All but 2 of the events occurred in unattended vehicles; however, environmental and intravehicular temperatures were recorded only for cases 9 and 10: a brother and sister found trapped together (these siblings were part of a previous report about childhood dehydration) (21). For these 2 cases, the intravehicular temperature was >50°C on the day of death, and the ambient temperature was 23°C (maximum 27°C). The body temperature of 2 children was 42.2°C (108°F) and for another victim was 40.1°C (104.2°F) when measured in the emergency department. A few hours after death, the body temperature of 3 other children was still at or above normal, and in 2 of these cases the parents had bathed the children after they were found, in an attempt to lower their body temperatures. All of the children in this series were either found dead or pronounced dead within 1 hour of being found.

There were no consistent caretakers among these cases. In all but 1 case, there was a single caretaker (female:male = 6:3); both parents were the caretakers in 1 case. Because 2 sets of children were found together (Table 1), this actually represents 5 female and 2 male caretakers.

Intrathoracic petechiae (IP) were the most consistent postmortem finding. These were present in all 8 children discovered in vehicles, and in 1 of the 2 children found in bed (Table 1). Dehydration was evident in 5 cases. Cutaneous injuries included petechiae in 2 cases, early skin slippage in 2, and a burn injury in 1. The skin "felt like 200 degrees" in 1 case. Blunt force trauma to the back was present in 1 case, wherein the manner of death was deemed homicide. Each of the twin siblings, both of whom were dehydrated, revealed acute hemorrhage in the tentorium (cases 1 and 2). Slight subarachnoid hemorrhage was present in another child who was also dehydrated (case 3). Severe pulmonary hemorrhage was present in case 3. Otherwise, the viscera were generally unremarkable except for skeletal muscle necrosis in 1 case and hepatic centrolobular degeneration in another. Finally, acute splenitis, characterized by mild sinusoidal neutrophilic infiltration, was seen in 2 cases (cases 3 and 6); DIC was not identified. Three children (cases 1, 2, and 4), all born prematurely, had body weights under the third percentile but were growing and developing normally. One child (case #5) had Down syndrome.

The manner of death was judged to be homicide in 4 cases and accidental in 6 cases. Tables 2 and 3 provide relevant details on the children reported to have died of environmental hyperthermia who were found in vehicles and beds, respectively.

DISCUSSION

Diagnosis and Risk Factors

The diagnosis of heat stroke is determined by a clinical presentation of disorientation, delirium, possible seizures, and coma and is confirmed by a body temperature ≥40.6°C (105°F) (22). The identification of the source of exposure to hyperthermia obviously aids in the diagnosis, especially when lower body temperatures are recorded after the victim has been moved into a cooler environment (3). Sustained exposure to heat is associated with a 50% mortality rate (23). Compared with adults, children are at greater risk of morbidity and mortality, given their larger body surface areas per unit of body weight and their reduced capacity for sweating (24). Underlying illness probably increases the risk, reflected in the report of an infant with bronchopulmonary dysplasia who died of environmental hyperthermia (25). The elderly, chronically ill, and disabled are also vulnerable (13).

Because there are consistent differences in the groups of children found in vehicles or beds, our cases are combined with those reported in the literature for the purposes of discussion.

Hyperthermia Victims Found in Vehicles

Among 18 children found in motor vehicles (cases 1–3, 5–7, and 9–10 in Table 1 and Table 2), 9 were female and 8 were male (the gender was not stated in 1 case). The ages ranged from 84 days to 9 years, with 10 children aged ≥1 year (the ages were not stated in 2 cases). Body temperatures were reported in 10 cases and ranged from 37°C measured 3 hours after death to 42.2°C (108°F). Nine children were exposed to high temperatures for ≤2 hours, and the range of exposure in all cases was between 1 and 10 hours. The caretakers were the mothers in 6 cases and the fathers in 3 cases. The manner of death was homicide, accidental, or unstated in 4, 5, and 9 cases, respectively.

Intrathoracic petechiae were identified in all 12 cases for which specific information was available; neither their presence nor their absence was reported in the other 6 cases. The other pathologic findings attributed to hyperthermic exposure included dehydration (6 cases), cutaneous burns (1 case), early skin slippage (2 cases), cutaneous petechiae (2 cases), and conjunctival petechiae (1 case). Disseminated intravascular coagulation was not identified in any of our cases but was identified in 2 reported cases (Table 2) wherein the children survived after discovery for 19 and 70 hours, respectively (1,6).

TABLE 1. *Summary of ten Southern California and South Australia cases*

Case #	Age, days	Sex	Site	Caretaker	Manner of death	Exposure, hrs	Survival, hrs	Body temperature	External exam	Other information	IP	DIC	Liver necrosis
1	84	M	Car, with case 2 (twin)	Mother	Homicide	1	Dead on arrival at ER	U	Evidence of dehydration; very warm to touch		Yes	No	No
2	84	F	Car, with case 1 (twin)	Mother	Homicide	1	Dead on arrival at ER	42.2°C (108°F)	Evidence of dehydration		Yes	No	No
3	1155 (3 yrs)	F	Car	Parents	Accident	≤3	Found dead	U	Evidence of dehydration; cutaneous petechiae		Yes	No	No
4	804 (2 yrs)	M	Bed; body and head completely wrapped in blanket; in jump suit damp with perspiration; congestion	Mother's fiance	Homicide	"afternoon" till 8:30 pm	Pronounced dead ≈45 min after found	U	Blunt force trauma to the back; evidence of mild dehydration		No	No	No
5	176	M	Van	Foster mother	Accident	3.5	Pronounced dead ≈30 min after found	42.2°C (108°F)	Skin slippage. cutaneous burns	Down syndrome	Yes	No	No
6	326	M	Car	Mother	Homicide	6	Found dead	37.8°C (100°F), 2 hr after found	Evidence of dehydration; skin "hot to touch"		Yes	No	No
7	256	M	Car	Grandmother	Accident	4	Found dead	U	"Skin felt 200 degrees", cutaneous petechiae		Yes	No	No
8	53	M	Bed; fever of 37.5°C (99.5°F) and cough; firemen noted residence was extremely warm; body with a gown, heavy cloth towel and diaper covered with light cotton blanket	Mother	Accident	6	Pronounced dead ≈1 hour after found	40.1°C (104.2°F) ½ hour after found unresponsive		Otitis media; given Dimetap night before death, contraindicated in children under 6 years of age	Yes	No	No
9	898 (3 yrs)	F	Car with case 10 (sibling)	Father	Accident	<2	Pronounced 12 minutes after found	37°C, ≈3 hours after death*			Yes	No	No
10	3191 (9 yrs)	M	Car, with case 9 (sibling)	Father	Accident	<2	Pronounced 12 minutes after found	41°C, ≈3 hours after death*	Early skin slippage		Yes	No	No

IP: Intrathoracic petechiae

DIC: Disseminated intravascular coagulation

U: Unknown

*When found, parents had bathed children to try to reduce their temperatures

TABLE 2. *Ten reported cases of lethal environmental hyperthermic exposure while in a vehicle*

Author	Age	Sex	Site	Caretaker	Manner of Death	Exposure, Hrs	Survival, Hrs	Body Temperature	External Exam	IP	DIC	Liver Necrosis
Roberts & Roberts, 1976[1]	19.5 months	F	Vehicle (not closed)	Mother	U	1	19 hours after found, was declared brain dead	42.2°C rectal		U	Yes	U
Zumwalt, Petty, and Holman, 1976[2]	2 years	F	Vehicle	Aunt	U	1	DOA	U		Yes	No	No
Zumwalt and Hirsch, 1980[5]	2 years	M	Vehicle (closed)	Father	Homicide	10	Found dead	U		U	U	U
King, Negus, and Vance, 1981[6]	U	F	Vehicle	Mother	U	2	Died 70 hours after found	41.5°C	Dehydration	U	Yes	U
King, Negus, and Vance, 1981[6]	U	U	Vehicle	U	U	Apparently several hours—went from shade to direct sunlight	Found dead	U		U	U	U
Hiss et al, 1994[9]	12 months	F	Vehicle (closed van)	U	U	4.5	Found dead	U	Dehydrated oral mucosa and skin, conjunctival petechiae	Yes	No	No
Donoghue et al, 1997[1]	3 years	M	Vehicle (closed SUV)	Day care provider	U	2	Pronounced 1 hour after found	41.7°C		Yes	No	No
Donoghue et al, 1997[11]	3 years	M	Vehicle (closed SUV)	Day care provider	U	2	Pronounced 1 hour after found	42.2°C		Yes	No	No
MMWR, 1997[10]	10 months	F	Vehicle	U	U	~5	Unknown, CPR not successful—couldn't have "survived" long	42.2°C (108°F) core		U	U	U
MMWR, 1999[13]	4 years	F	Vehicle	Unknown—probably child care worker	Probable accident—"disappeared from child care center"	Disappeared at 10 am found at 4: 47 pm	Found dead	U		U	U	U

IP: Intrathoracic petechiae; DIC: Disseminated intravascular coagulation; U: Unknown

TABLE 3. *Continued*

Caretaker	Manner of death	Exposure, hrs	Survival, hrs	Body temperature	External exam	IP	DIC	Liver necrosis
Parents	Assumed accident	Overnight	29 hours after admission	39.9°C oral	Mild dehydration when found	U	Yes	Yes
U	Assumed accident	Overnight	25 hours after admission	41°C rectal	Mild dehydration when found	U	Yes	Yes
Mother	Assumed accident	Overnight	26 hours after admission	40.1°C rectal, 90 minutes after found		U	Yes	Yes
Unknown, Found by mother	Assumed accident	Overnight	6 hours after admission	U	"Very hot trunk"; purpura	U	Yes	Yes
Parents	Assumed accident	7 (overnight)	Found dead	U	Noted to be "very hot" by father 75 minutes prior to identified death	Yes	No	No
U	Originally SIDS, probably accident	4.5 (overnight)	Found dead	U		U	U	U
U	Originally, pneumonia, probably accident	U	U	U		U	U	U
Mother	Referred to as an accident	5	Death confirmed ≈40 minutes after admission	41.3°C at first, 40.4°C ½ hour later at death	A 2nd degree burn on the eyebrow and left hand and a 1st degree burn on the cheek	Yes	No	No
Father	Accidental fatality due to physical violence (atypical unintentional child abuse)	6	Found dead	U	Anisocoria, plucked scalp hairs were grasped with left hand; cutaneous petechiae of the upper chest; small healing abrasion on the head and some small, fresh, subcutaneous bleedings on the head and chest	Yes	No	No

IP: Intrathoracic petechiae
DIC: Disseminated intravascular coagulation
U: Unknown

homicide and the latter was interpreted as an example of atypical fatal child abuse (12). Liver necrosis and DIC were present in 4 cases, and, as with the children found in vehicles, were identified only in children that survived for at least 6 hours after discovery. Hepatic centrolobular degeneration was detected in 1 child who had been in bed for 6 hours and did not survive after being found.

This group of children typically overheated through a combination of several factors that included excessive wrapping or thick covers, elevated room temperatures caused by either high ambient temperatures and humidity or excessive use of indoor heat sources in close proximity to the infant. Some of the children had mild fever or infections, and in 1 case the infant's self-exertion was thought to have contributed to overheating (Table 3) (12).

Comments

The children dying of hyperthermic exposure in vehicles differ from those discovered in beds. Children found in vehicles are nearly divided equally between male and female children, whereas those discovered in a bed are typically male. The children found in vehicles tend to be older than those discovered in beds. There are several possible explanations for this age difference. Because infants are more vulnerable than toddlers to a variety of risks, including hyperthermia, caretakers may be more protective and likely to monitor them and, therefore, less likely to leave them unattended for longer lengths of time. Similarly, caretakers may be more likely to leave a young child in a vehicle, rather than an infant, particularly if the child is sleeping. A 1976 survey revealed that

lar tonsillar herniation, as well as pulmonary hemorrhage and left ventricular subendocardial hemorrhage. Gastrointestinal and mesenteric hemorrhage, focal myocardial necrosis, renal tubular necrosis, adrenal necrosis, and rhabdomyolysis have also been identified. As with liver cell necrosis and DIC, these changes develop in victims who survive for some time after the hyperthermic event and are not specific to the location where the victim is discovered.

The manner of death was considered accidental when the investigation indicated miscommunication among the caretakers, or if the child entered the vehicle without the caretaker's knowledge, as occurred in 3 of our cases and apparently in 1 reported case (13). In case 3, a 3-year-old who had been playing in the family car was thought by the parents to be at a neighbor's house with a fellow playmate. In cases 9 and 10, a brother and sister climbed into the back of a station wagon to play and were trapped as a result of a cargo barrier. Death in infants found overwrapped or in an overheated sleeping environment are also considered accidental, lending support to the notion that some parents have adopted the misguided belief that babies should be kept very warm to manage or prevent upper respiratory illnesses (34). The manner of death was homicide in 5 cases on the basis of inflicted trauma and circumstances indicating neglectful parenting (5). The child in case 4 died under suspicious circumstances and had evidence of inflicted trauma. Neglect and poor parenting of a 2-year-old boy left in a vehicle while his father visited several taverns contributed to the designation of homicide in 1 of the reported cases (5). Although the manner of death was not reported, the presence of conjunctival petechiae in 1 case (9) should not be considered a marker of homicide, given that petechiae were present elsewhere in the body. On the other hand, petechiae limited to the conjunctiva in a victim of ostensible hyperthermic exposure should perhaps raise the question of previous suffocation or strangulation (35).

Hyperthermia may be a contributory factor in deaths with other apparent causes. Bass reported 3 such cases in which the likely cause of death was hyperthermia and asphyxia in addition to possible carbon monoxide exposure in 2 cases and the use of a plastic tent attached to a steam vaporizer in the other (7). In all these cases, the manner of death appears to have been accidental.

Recommendations

This analysis prompts several recommendations intended to assist in the evaluation of hyperthermic death in infants and young children. The description of the scene where the victim was discovered should include measurement of ambient and body temperatures and the source of environmental hyperthermia. It is noteworthy that the body temperature was not measured in 4 of our cases and not reported in 10 of the 19 cases in the literature. The vehicle's make, color, and window and door position, as well as exposure to direct sunlight, should be noted. In those children found in bed, the scene analysis should include a description of bedmates with their mental status and size, the type and amount of bedding, and other items in the bed, such as pillows and overstuffed toys. Photographs and diagrams of scene reconstructions accompanied by comprehensive descriptions with a doll can offer important information regarding the position of the victim in relation to bedmates, blankets, the victim's clothing, and devices designed to increase ambient temperatures, such as space heaters. The circumstances allowing a child to succumb to environmental hyperthermia must be analyzed to determine whether the manner of death is an accident or homicide. In this regard, verification of the caretakers' understanding of their responsibilities regarding the child's welfare is critical. The postmortem findings can be critical in delineating the severity and length of hyperthermic exposure experienced by the victim.

Acknowledgment: The authors thank the National SIDS Alliance, C.J. Foundation, the San Diego Guild for Infant Survival, and the Orange County Guild for Infant Survival, which provided grant support for this study; the many parents of SIDS victims who generously donated to the San Diego SIDS Research Project; the deputy medical examiners, scene investigators, and staff of the Office of the Medical Examiner of San Diego County; Ms. Jacqueline Berndt, Chief Deputy Coroner of Orange County in California; and Mr. Wayne Chivell, the South Australian State Coroner, for permission to publish details of the South Australian cases.

REFERENCES

1. Roberts KB, Roberts EC. The automobile and heat stress. *Pediatrics* 1976;58:101–4.
2. Zumwalt RE, Petty CS, Holman W. Temperatures in closed automobiles in hot weather. *Forensic Sci Gaz* 1976;7:7–8.
3. Bacon C, Scott D, Jones P. Heatstroke in well-wrapped infants. *Lancet* 1979;1:422–5.
4. Goodyear JE. Heat hyperpyrexia in an infant: A case report. *Med Sci Law* 1979;19:208–9.
5. Zumwalt RE, Hirsch CS. Subtle fatal child abuse. *Hum Pathol* 1980;11:167–74.
6. King K, Negus K, Vance JC. Heat stress in motor vehicles: A problem in infancy. *Pediatrics* 1981;68:579–82.
7. Bass M, Kravath RE, Glass L. Death-scene investigation in sudden infant death. *N Engl J Med* 1986;315:100–5.
8. Ohshima T, Maeda H, Takayasu T, Fujioka Y, Nakaya T. An autopsy case of infant death due to heat stroke. *Am J Forensic Med Pathol* 1992;13:217–21.
9. Hiss J, Kahana T, Kugel C, Epstein Y. Fatal classic and exertional heat stroke: Report of four cases. *Med Sci Law* 1994;34:339–43.
10. Heat-related deaths–Dallas, Wichita, and Cooke counties, Texas, and United States, 1996. *MMWR* 1997;46:528–31.
11. Donoghue ER, Graham MA, Jentzen JM, Lifschultz BD, Luke JL, Mirchandani HG. Criteria for the diagnosis of heat-related deaths: National Association of Medical Examiners. Position

paper. National Association of Medical Examiners Ad Hoc Committee on the Definition of Heat-Related Fatalities. *Am J Forensic Med Pathol* 1997;18:11–4.
12. Zhu BL, Ishida K, Fujita MQ, Maeda H. Infant death presumably due to exertional self-overheating in bed: An autopsy case of suspected child abuse. *Nippon Hoigaku Zasshi* 1998;52: 153–6.
13. Heat-related illnesses and deaths–Missouri, 1998, and United States, 1979–1996. *MMWR Morb Mortal Wkly Rep* 1999;48: 469–73.
14. Surpure JS. Heat-related illness and the automobile. *Ann Emerg Med* 1982;11:263–5.
15. Gibbs LI, Lawrence DW, Kohn MA. Heat exposure in an enclosed automobile. *J La State Med Soc* 1995;147:545–6.
16. Chao TC, Sinniah R, Pakiam JE. Acute heat stroke deaths. *Pathology* 1981;13:145–56.
17. Gordon I, Shapiro HA, Berson SD. *Forensic Medicine: A Guide to Principles*, 3rd ed. Edinburgh: Churchill Livingstone, 1988.
18. Di Maio DJ, Di Maio VJM. *Forensic Pathology*. New York: Elsevier, 1989.
19. Lifschultz BD, Donoghue ER. Forensic pathology of heat- and cold-related injuries. *Clin Lab Med* 1998;18:77–90.
20. Danks DM, Webb DW, Allen J. Heat illness in infants and young children. *BMJ* 1962;2:287–93.
21. Byard RW, Bourne AJ, James R. Childhood deaths and cargo barriers in cars. *J Paediatr Child Health* 1999;35:409–10.
22. Heat–related illnesses and deaths: United States, 1994–1995. *MMWR* 1995;44:465–8.
23. Behrman RE, Kliegman RM, Jenson HB, eds. *Nelson Textbook of Pediatrics*, 16th ed. Philadelphia: WB Saunders, 2000.
24. Climatic heat stress and the exercising child and adolescent. American Academy of Pediatrics Committee on Sports Medicine and Fitness. *Pediatrics* 2000;106(1Pt1):158–9.
25. Heat-wave–related mortality: Milwaukee, Wisconsin, July. *MMWR* 1996;1995;45:505–7.
26. Gregory NG, Constantine E. Hyperthermia in dogs left in cars. *Vet Rec* 1996;139:349–50.
27. Thomas KT. Enclosed automobiles and the risk of hyperthermia. *Nurse Practitioner* 2000;25:14–7.
28. Poets CF, Meny RG, Chobanian MR, Bonofiglo RE. Gasping and other cardiorespiratory patterns during sudden infant deaths. *Pediatr Res* 1999;45:350–4.
29. Serdarevich C, Fewell JE. Influence of core temperature on autoresuscitation during repeated exposure to hypoxia in normal rat pups. *J Appl Physiol* 1999;87:1346–53.
30. Fadic R, Larrain C, Zapata P. Thermal effects on ventilation in cats: participation of carotid body chemoreceptors. *Respir Physiol* 1991;86:51–63.
31. Krous HF. The microscopic distribution of intrathoracic petechiae in sudden infant death syndrome. *Arch Pathol Lab Med* 1984;108:77–9.
32. Guntheroth WG, Spiers PS. Thermal stress in sudden infant death: is there an ambiguity with the rebreathing hypothesis? *Pediatrics* 2001;107:693–8.
33. Eshel GM, Safar P, Sassano J, Stezoski SW. Delayed death after uncomplicated hot tub bathing in dogs and monkeys. *Resuscitation* 1998;37:189–95.
34. Bacon CJ. Overheating in infancy. *Arch Dis Child* 1983;58: 673–4.
35. Betz P, Hausmann R, Eisenmenger W. A contribution to a possible differentiation between SIDS and asphyxiation. *Forensic Sci Int* 1998;91:147–52.