Certification of Vehicular Hyperthermia Deaths in the Pediatric Population

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ABSTRACT

The investigation of vehicular hyperthermia deaths in infants and children requires coordination between the autopsy, clinical history, and scene investigation. Unfortunately, autopsy findings can be limited or nonspecific, clinical history may be unavailable, and details concerning ambient temperature and vehicular temperature may be vague. In cases where hyperthermia is established as the cause of death, the certification of manner of death can be challenging and inconsistent among medical examiners. This article provides an overview of vehicular hyperthermia deaths and the certification of cause and manner of death in these cases. *Acad Forensic Pathol. 2016 6(4): 657-662*

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Roles: Project conception and/or design, data acquisition, analysis and/or interpretation, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work.

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ETHICAL APPROVAL

As per Journal Policies, ethical approval was not required for this manuscript

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This article does not contain any studies conducted with animals or on living human subjects

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DISCLOSURES & DECLARATION OF CONFLICTS OF INTEREST

The author, reviewers, editors, and publication staff do not report any relevant conflicts of interest

FINANCIAL DISCLOSURE

The author has indicated that he does not have financial relationships to disclose that are relevant to this manuscript

KEYWORDS

Forensic pathology, Hyperthermia, Vehicular deaths, Pediatric, Cause and manner

INFORMATION

ACADEMIC FORENSIC PATHOLOGY: THE OFFICIAL PUBLICATION OF THE NATIONAL ASSOCIATION OF MEDICAL EXAMINERS
 • (ISSN: 1925-3621) • https://doi.org/10.23907/2016.061
Submitted for consideration on 7 Oct 2016. Accepted for publication on 27 Oct 2016

INTRODUCTION

Motor vehicles have been a source of potential danger for children since their creation. Hazards include passenger blunt force trauma related to vehicular accidents, rollovers and backovers of children outside of vehicles, carbon monoxide poisonings, and heat-related injuries and deaths. The first child restraint laws began to appear in 1979, and now car carriers, rear-facing car seats, and booster seats are commonplace (1). Innovations to prevent vehicular injuries in children are constantly evolving and include rear cameras, backup sensors, and other devices. Ironically, increases in the use of infant carriers and car seats have resulted in an increase in heat-related deaths within vehicles (2).

Vehicular hyperthermia deaths often occur during the summer, and occur more often in hotter climates. Infants and toddlers are most at risk, particularly because older children may extract themselves or alert others for help (2). Forensic pathologists are tasked with identifying heat-related injuries and assigning a manner of death. Cause of death may be challenging due to limited autopsy findings, and manner of death has been inconsistent between jurisdictions.

DISCUSSION

Temperature Regulation

Humans operate normally at a temperature of 98.2 ± 0.7°F (36.8 ± 0.4°C), reflecting the net sum of metabolic processes in the body (3, 4). Fit adults can tolerate transient changes in internal temperature ±7.2°F (4°C) without substantial impact to function. This range is narrower for susceptible populations such as the elderly, children, and those with significant natural disease such as cardiovascular disease. Higher metabolic rate, reduced capacity for sweating, greater thermolability, and larger body surface-to-volume ratio make infants and young children more susceptible to hyperthermia (5).

Hyperthermia occurs when the thermoregulatory mechanisms can no longer effectively dissipate heat (3). Through the function of the preoptic anterior hypothalamus, the body maintains core temperature through many different mechanisms such as vasodilation or vasoconstriction, sweating and shivering, and alterations to physical activity. Additional actions include layering/shedding of clothing, changing the environmental temperature (air conditioning), or changing locations.

The body controls heat loss through both intrinsic and extrinsic pathways. The intrinsic pathways are managed by the circulatory system – the managing of heat through the interface of the circulation and the skin, subcutaneous tissues, and lungs. Extrinsic mechanisms of heat loss include conduction, convection, radiation, and evaporation (**Table 1**) (3). Within an enclosed vehicle, heat loss via conduction, convection, and radiation are negligible; evaporation has some effect but is quickly overwhelmed in this environment (6).

Table 1: Extrinsic Thermoregulation (3)

Conduction	The transfer of heat from the skin surface to air or another opposing surface. Heat will flow from higher to lower temperatures, thus heat loss will not occur in high environmental temperatures such as enclosed vehicles. Not surprisingly, transfer of heat is far more efficient (up to 25x greater) between the skin surface and water as opposed to air. Conduction may be slowed by insulation such as increased amounts of subcutaneous fat. In children, conduction is greater due the relatively small amount of subcutaneous fat compared to adults.
Convection	Continuous heat loss due to movement of air over the skin surface. Unless the windows are down, there is no air flow within an enclosed vehicle.
Radiation	Radiative heat in the environment from solar energy (both direct and indirect). It is this radiative heat from solar energy that provides the marked increase in interior temperatures within vehicles.
Evaporation	A small amount of moisture evaporates from the skin and lungs, constituting insensible heat loss. At higher temperatures, perspiration is triggered, resulting in much higher levels of heat transfer through evaporation. High humidity interferes with perspiration by dramatically reducing the rate of evaporation. In these environments, sweating continues but evaporation is limited.

Vehicles in Sunlight

Several studies have demonstrated marked increases in temperature within vehicles, especially those exposed to direct sunlight. King et al. demonstrated that temperatures can rise rapidly within enclosed vehicles, often reaching maximum temperatures within five minutes. In an open area with an ambient temp of 36.8°C (98°F), interior temperatures reached 51-67°C (124-152°F) within 15 minutes of closing the doors (5, 7).

Variables that affect temperatures within vehicles include the type and size of the vehicle, the ambient temperature, the amount of direct sunlight, and even to some degree, the color of the vehicle. In a study by Zumwalt et al., interior temperatures (passenger and trunk areas) were recorded in two different vehicles at different times of the afternoon over the course of several months (6). One vehicle was white and the other was blue; both cars were in direct sunlight. Daily variables over the course of the study included ambient outside temperature, humidity, cloud cover, wind, and angle of the sun. Ambient temperatures ranged from 82-97°F depending on the time of day. Temperatures in the test vehicles averaged 20-30 degrees hotter than the ambient temperature. Temperatures within the blue car rose to 112-136°F, with little difference between the passenger and trunk areas. Temperatures within the white vehicle varied somewhat between the passenger area (102-132°F) and trunk area (100-112°F), with the trunk compartment consistently measuring cooler.

The study by King et al. also examined light and dark vehicles, but included other factors such as window position and cabin humidity. White vehicles were somewhat cooler than dark vehicles, consistent with previous studies. Of note, a similar temperature reduction was seen in dark vehicles with white roof panels. Slightly "cracking" the windows (lowered 50 mm) provided only a mild decrease in interior temperatures when compared to closed vehicles (50.5°C and 66.4°C respectively). However, lowering the windows at least half way (lowered 200 mm) brought internal temperatures down significantly more (40.9°C) (7).

Cause of Death

In 1997, the National Association of Medical Examiners (NAME) position paper on heat-related deaths defined heat-related deaths as "… *a death in which exposure to high ambient temperature either caused the death or significantly contributed to it*" (8). Patients presenting to the emergency room will have high body temperatures (defined as ≥ 105°F) and elevated liver and muscle enzymes. Symptoms will include changes in mental status, tachypnea, and tachycardia, with normal or possibly decreased blood pressure (8, 9). However, these findings are obviously unavailable if the individual is found dead at the scene, and findings at autopsy are often minimal and nonspecific.

In forensic cases, body temperature may not be available or may be obscured by other factors. If the body is exposed to a hot environment, it is sometimes unclear if an elevated body temperature is due to a true hyperthermia, or if the decedent died from some other cause and then the body temperature rose in accordance with the surrounding environment. A high temperature environment also contributes to accelerated decomposition, further limiting the information the autopsy may provide. Body temperature may also be complicated by actions of the caregiver after discovery. In one study of environmental hyperthermia deaths, two cases had lower body temperatures due to bathing by the caregivers to lower the temperature (10).

Nonspecific autopsy findings described in hyperthermia cases include intrathoracic petechiae, pulmonary edema, cerebral edema, and liver necrosis. Electrolytes may show a dehydration pattern, but exposure to high temperatures may cause death before significant dehydration can occur. In one study, a third of the cases showed evidence of dehydration (10).

Occasionally, the skin may show burns due to seat belt buckles, steering wheels, or vinyl upholstery. Several studies have shown that these surface temperatures can be even higher than recorded interior temperatures (11, 12). In addition, prolonged heat exposure may cause skin slippage and cutaneous petechiae.

Up to 40% of children under the age of 14 succumb to hyperthermia due to entrapment in vehicles (13). Children who survive these events can manifest long-term cognitive and motor disabilities. Acute mechanisms of death include cardiac arrhythmia, seizures, or shock. Prolonged survival intervals progress to disseminated intravascular coagulation, shock, and multiorgan failure.

The cause of death in these cases can be classified simply as "hyperthermia," or perhaps "complications of hyperthermia" if there is a prolonged hospital course. The term "heat-related death" could also be used, but this information may be more appropriate under "how injury occurred" on the death certificate. The "how injury occurred" section of the death certificate may also include phrases such as "high environmental temperature," "entrapped in vehicle," or even "unattended child in vehicle."

Manner of Death

The NAME 1997 position paper on heat-related deaths establishes criteria for certification of cause of death, but does not discuss manner of death. Many jurisdictions classify most vehicular hyperthermia cases as accidents. Caregivers have forgotten infants in the back seat of a vehicle, or in some cases (particularly larger vehicles such as vans and busses), the child may be sleeping or even hiding. However, if there is willful negligence or blatant disregard for safety, the manner may be classified as homicide. Some jurisdictions take an extreme stance of classifying all vehicular hyperthermia deaths as homicides.

In one study involving 171 hyperthermia deaths of children in vehicles, 27% gained access to an unlocked car and 73% were intentionally or accidently left in a vehicle (14). In cases involving toddlers and children gaining access to a vehicle, determination of poor/absent supervision or gross neglect requires detailed scene information: 1) How many people were in the residence/daycare? Who was responsible for watching the child? 2) How many other children were at the residence/daycare? 3) How long did it take to find the child? 4) What was the caregiver doing at the time the event occurred?

Table 2 gives multiple scenarios of vehicular heat-related deaths, demonstrating some of the variables considered in establishing manner of death. Medical examiners will have to decide for themselves where the transition point between accident and homicide lies. Comparisons can be made to bathtub drowning deaths of infants and toddlers. If a caregiver leaves an infant unsupervised in a bathtub, would it be considered an accident or homicide? As in the examples provided in **Table 2**, the determination of manner may be based on the length of time the infant was left unsupervised and possibly the actions of the caregiver during this time of negligent supervision.

Prosecution of vehicular hyperthermia proves to be even more variable than manner of death. In a study

Table 2: Vehicular Hyperthermia Scenarios

A father traveling with seven children in a van accidentally leaves a 21-month-old in the vehicle, assuming one of the other children helped the toddler out of his car seat. One hour later, the father realizes that the toddler is not in the house and finds him unresponsive in the van.
A mother working several jobs does not realize she did not drop off her 5-month-old infant at daycare. She goes to work, leaving the infant in the vehicle. When the mother takes her lunch break, she finds the infant unresponsive in the car.
A father traveling with seven children in a van accidentally leaves a 21-month-old in the vehicle, assuming one of the other children helped the toddler out of his car seat. Two hours later, the father realizes that the toddler is not in the house and finds him unresponsive in the van. However, the father waits an additional 45 minutes to call 911 while trying to revive the infant at home.
A father traveling with seven children in a van accidentally leaves a 6-month-old in the vehicle. Twelve hours later, he realizes the child is missing and finds him unresponsive in the van.
A mother intentionally leaves her 5-month-old infant in her vehicle while she goes to a 30 minute job interview.
A mother intentionally leaves her 5-month-old infant in her vehicle while she goes to get her hair done at the salon.
A mother intentionally leaves her 5-month-old infant in her vehicle while she goes into a crack house to purchase and use drugs.

by Collins, data on vehicular hyperthermia cases from 1998 to 2003 were collected, specifically looking at the outcomes of 130 incidents involving 136 victims (**Table 3**) (15). The prosecution rate clearly varied depending on who the defendant was, with unrelated caregivers having the highest rate (88.8%). The conviction rates for all categories are high, mostly due to a high number of guilty pleas. Offenses ranged from involuntary manslaughter to (in one case) second-degree murder. As with determination of manner of death, offenses were higher if willful intent was established. In the second-degree murder case, the mother intentionally left her children in a car while having her hair done.

Many cases of vehicular hyperthermia are considered tragic accidents and not prosecuted. However, these data indicate that if the decision is made to prosecute, a conviction is likely. In cases that included additional aggravating factors such as drug or alcohol abuse prior to the event, prosecution was almost always pursued.

The Collins study also identified what appeared to be a significant difference in prosecution based on socioeconomic status (15). In 51 cases in which socioeconomic data were available, 30 cases involved "white collar" professions. The prosecution rate for these caregivers was 23.3%. However, of the 21 caregivers that were "blue collar" or unemployed, the prosecution rate was 85.7% (15).

Public Attention and Recent Legislation

According to KidsAndCars.org, the average number of child vehicular hyperthermia deaths averages 37 per year, with a general upward trend since the 1990's (16). At the time of this publication, there have been 37 documented deaths in 2016. A news article from 2001 cited that in the first six months of that year, firefighters in Dallas, TX responded to over 200 incidents of children left unattended in vehicles (17).

The highest numbers of deaths have been reported in southern states such as Texas, Florida, and California. As of 2016, 19 states have laws that specifically address leaving a child unattended in a vehicle. In addition, ten states specifically protect citizens from civil liability if they break into a car to rescue a child or pet. Texas, which has had the most vehicular hyperthermia deaths thus far in 2016, is proposing a similar bill this legislative session (18).

In September of 2016, the Helping Overcome Trauma for Children Alone in Rear Seats Act (HOT CARS Act, H.R. 6041) was introduced by representatives from Ohio, New York, and Illinois. This act calls on the National Highway Traffic Safety Administration to require manufacturers of new vehicles to include a reminder system that alerts a driver if a child is left unattended in a vehicle (19). At this time, the legislation has been referred to the House Committee on Energy and Commerce.

CONCLUSION

Vehicular hyperthermia deaths in children continue to occur in high numbers, despite being completely preventable. Recent legislative efforts regarding unattended children in vehicles highlight this ongoing public health issue, going so far as to recommend additional vehicular safety features and liability protection for those people acting to rescue unattended

Table 3: Prosecution and Conviction (15)

Defendant	Number of Incidents	Incidents Prosecuted	Convicted
Mother	46	60.5%	92%
Father	28	44%	90.9%
Both parents	14	50%	83.3%
Other relative	14	60%	83.3%
Unrelated	28	88.8%	90.9%

children within vehicles. The diagnosis of hyperthermia in forensic pathology may often rely on scene investigation and witness interviews rather than gross and microscopic findings. Determination of manner of death also relies on information outside of the autopsy, and may not be consistent between jurisdictions.

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