Pediatric Heatstroke Fatalities Caused by Being Left in Motor Vehicles

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Objectives: Fatalities due to being left in motor vehicles is an important cause of pediatric mortality. Few studies in the medical literature focus on this topic. This study aims to describe the circumstances surrounding these deaths, to determine their geographic distribution, and to evaluate the legal consequences for those responsible.

Methods: This is a retrospective cohort study of individuals ≤14 years old who died of heatstroke after being left in motor vehicles from 1990 through 2016 using a database provided by KidsAndCars.org. Descriptive data and specified outcomes regarding victims and responsible individuals were recorded.

Results: Of the 541 cases included for analysis, 528 fatalities involved a single victim and 26 fatalities involved 2 or more victims left in a vehicle. Of all fatalities, 54.4% were male and the mean age was 16.4 (±13.7) months. The responsible individual(s) unknowingly left the victim(s) in the vehicle in 78.2% of cases and knowingly left the victim(s) in 16.6% of cases. A single individual was responsible for leaving the victim(s) in 88.9% of cases. The cases were noted in 45 of 50 states and most commonly occurred in Texas (15%), Florida (12%), and California (7%). Criminal charges against the responsible individual(s) occurred in 58.2% of cases.

Conclusions: Pediatric fatalities due to being left in motor vehicles most commonly occur when a caregiver leaves a child unknowingly in a home parking area. These fatalities occur most often in Texas, Florida, and California. Responsible individuals are frequently charged with a crime.

Key Words: pediatric heatstroke, pediatric hyperthermia, nontraffic injury, motor vehicle

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Motor vehicle crashes account for numerous childhood deaths and injuries each year. Nontraffic injuries also pose a significant risk of morbidity and mortality in the pediatric population. Dangers to children in and around motor vehicles include, but are not limited to, power window strangulation, trunk entrapment, and backovers.[1–4] Congress has mandated the automobile industry to develop and install technology in the forms of safer power window switches,[5] emergency trunk releases, and back-up cameras,[6,7] which have reduced the incidence of these injuries.[8]

Heatstroke due to being left in motor vehicles is another important nontraffic injury causing morbidity and mortality in this population. The recent legislative proposal of the Helping Overcome Trauma for Children Alone in Rear Seats Act of 2017 has increased public awareness of this problem. However, little has been published in the medical literature to exclusively highlight this issue. Much of the challenge in studying this subject rests in reliable data collection. Lack of specific *International Classification of Disease* coding for this problem and inconsistent use of these codes make it difficult to use Centers for Disease Control and Prevention databases.[9,10] Furthermore, data collected by the National Highway Traffic Safety Administration (NHTSA) are limited by lack of a mandate for states to report injuries and deaths caused by nontraffic accidents, and there is an inconsistent level of detail available in the cases that are reported.[10] In fact, the NHTSA's national estimates are derived from data based on only 5 states.

Few studies have focused on heatstroke fatalities resulting from children being left in or independently gaining access to motor vehicles.[9–11] The objectives of this study were to describe the circumstances of heatstroke fatalities involving children left in motor vehicles, to determine the geographic distribution of these deaths in the United States, and to determine the legal consequences of those deemed responsible. It is important to study this subgroup of pediatric heatstroke fatalities to provide practitioners with information for anticipatory guidance and to lobby for potential technological innovations, which may eliminate this avoidable cause of childhood death.

METHODS

Study Design and Study Population

This was a retrospective cohort study of victims who died of heatstroke after being left in motor vehicles between January 1, 1990, and December 31, 2016, using a database provided by the national nonprofit KidsAndCars.org (KAC). The study population included victims ≤14 years old who died as a result of being left in motor vehicles. We excluded victims who gained access to a vehicle independently, whose caregivers remained in the vehicle, whose means of accessing the vehicle were unknown, and who sustained nonfatal injuries.

Database

KidsAndCars.org is a national nonprofit organization dedicated to promoting the safety of children in and around motor vehicles through data collection, research and analysis, education, public awareness, policy change, product redesign, and advocacy. This organization has collected data regarding nontraffic motor vehicle injuries and deaths in the United States retrospectively from 1990 to 1995 and prospectively from 1995 to present day. KidsAndCars.org defines nontraffic motor vehicle incidents as those involving injury or death that take place off public roads and highways, occurring mainly in parking lots and driveways.[12]

KidsAndCars.org finds cases by using media reports, Internet searches, Google alerts, and an Internet media monitoring service (Meltwater). After an incident is identified, key data points are extracted from the media report to create a case file.

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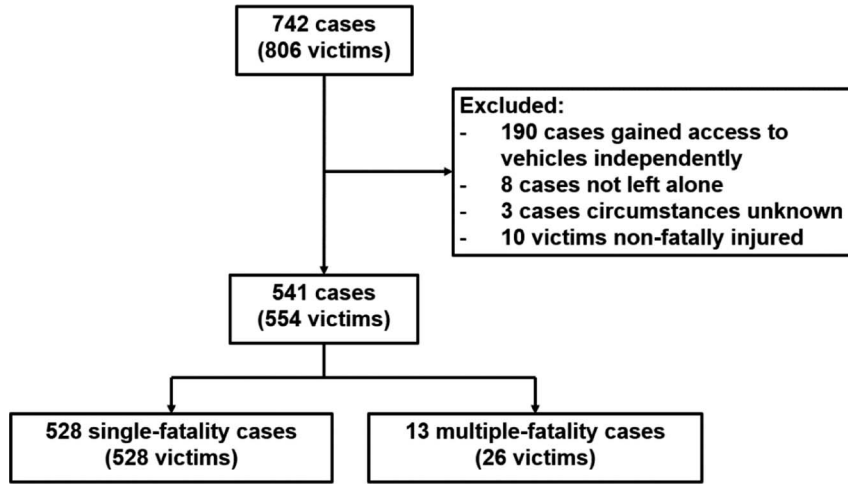

FIGURE 1. Flow of cases and number of single-fatality and multiple-fatality cases.

Supplemental data are assembled using a compilation of sources including police reports, medical examiner or coroner reports, court files, accounts from the victims' families, and child death review teams to complete the extensive 75 data elements per case.

Analysis

Descriptive data were extracted from the KAC database including general information regarding the incident (date, time, ambient temperature, location, number of victims involved, and circumstances by which the victim was left in the vehicle), the victim (age and sex), the responsible person(s) (sex, relation to the victim, and if criminal charges were filed), and whether or not drug and/or alcohol use was documented. Means, medians, and SDs were calculated for continuous variables. Counts and proportions or percentages were calculated for categorical variables.

RESULTS

A total of 742 cases occurring from January 1, 1990, to December 31, 2016, involving 806 heatstroke victims were reviewed. There were 190 cases (230 victims) excluded because the victims gained access to vehicles independently. An additional 8 cases involving 9 victims were excluded because the victims'

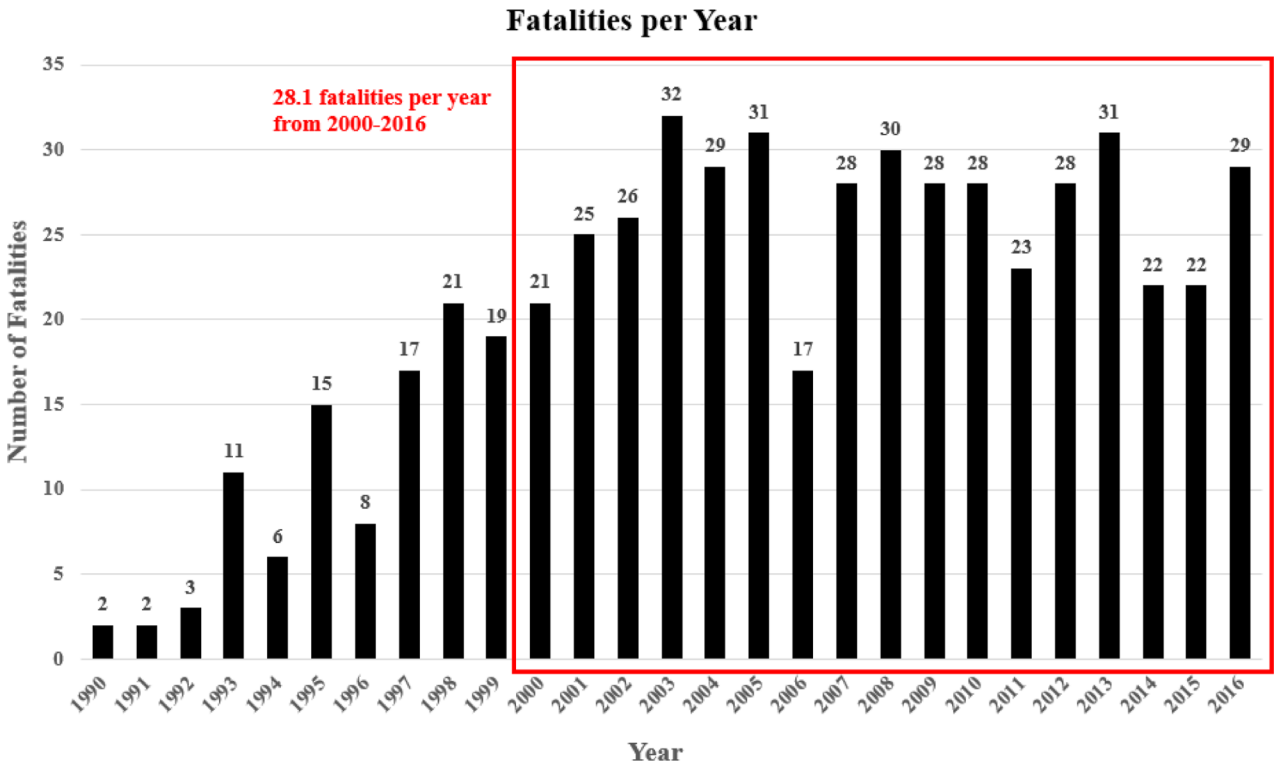

FIGURE 2. Number of fatalities per year due to children being left in motor vehicles. Note that from 2000 to 2016 the average number of fatalities per year increased to 28.1.

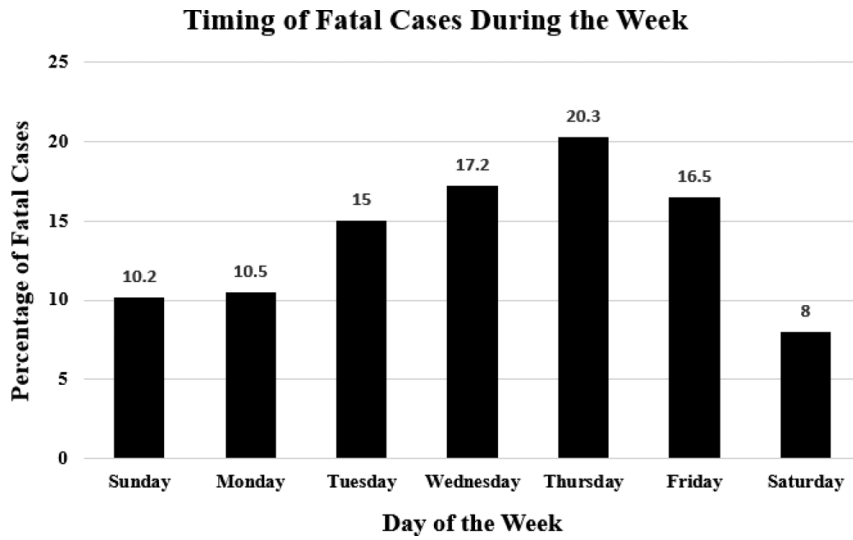

FIGURE 3. Day of the week cases occurred. Day of the week was unknown in 1.8% of cases.

caregivers remained in the vehicles, and 3 cases involving 3 victims were excluded because the circumstances by which the victims gained access to the vehicles were unknown. Lastly, 10 victims were excluded because they sustained nonfatal injuries. Ultimately, 541 cases involving 554 victims were included for analysis. Of these, there were 528 single-fatality cases and 13 multiple-fatality cases involving 26 victims (Fig. 1).

During the study period, there was an average of 21.3 fatal cases per year (Fig. 2). From January 1, 2000, to December 31, 2016, the average number of fatalities per year increased to 28.1. The victims were left in the vehicles for an average of 296 (±208) minutes. Nearly half (48.9%) of the cases occurred when the temperature was greater than 90°F, and 10.2% of cases occurred when the temperature was less than 80°F. Fatal cases most often happened during weekday, with the majority occurring on Wednesday (17.2%), Thursday (20.3%), and Friday (16.5%; Fig. 3). Fatal cases occurred most commonly in the morning hours of 7:00 AM (8.3%), 8:00 AM (12.6%), and 9:00 AM (11.8%), and in the afternoon hours of 2:00 PM (7.9%) and 3:00 PM (7.0%; Fig. 4). Fatalities were documented in 45 of the 50 states, with no cases in Alaska, Nebraska, Rhode Island, Vermont, or Wyoming. Texas, Florida, and California were the states where heatstroke fatalities occurred most, accounting for 15%, 12%, and 7% of all cases, respectively. Most incidents happened in home parking areas including home driveways and parking lots of apartment complexes (39.6%; Table 1). Nonresidential parking lots and street parking were the location of fatalities in 26.3% of cases, and daycare centers were the location of fatalities in 8.7% of cases.

The median victim age was 13 months, and the mean age was 16.4 (±13.7) months. Although nearly all victims were less than 5 years of age (99.3%), there were 4 older children who died of heatstroke after being left in a motor vehicle. Three of these

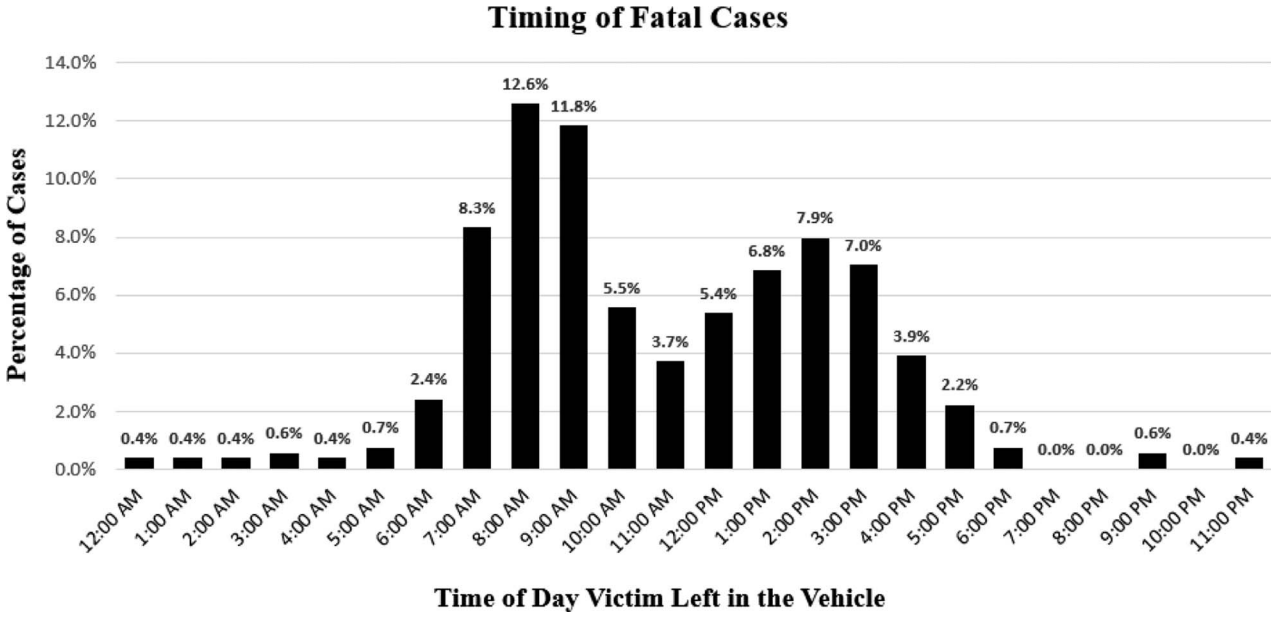

FIGURE 4. Timing of cases. Time victim was left in the vehicle was unknown in 18% of cases.

TABLE 1. Percentages of Fatalities by Location

Case Location	Percentage of Cases
Home parking	39.6
Parking lot or street parking	26.3
Daycare center parking	8.7
Store parking	4.8
Other	4.3
School parking lot	4.1
Medical facility parking lot	3.2
Church parking lot	3.2
Unknown	4.3

Store parking includes retail locations, malls, shopping centers, and grocery stores. "Other" parking locations included parking at restaurants, hotels/motels, parks, campgrounds, beaches, casinos, and so on.

victims were knowingly left in the car. An 8-year-old boy was left in the trunk of a car because of an inability for the caregiver to obtain childcare while working. A 14-year-old boy succumbed to the effects of heatstroke after being left in a pick-up truck by smugglers, and a 5-year-old boy died of environmental hyperthermia after being left in the flatbed of a pick-up truck. The fourth case resulted after the caregiver unknowingly left a 5-year-old child in his car seat along with his 3-year-old brother resulting in the deaths of both victims. Victim sex was 54.4% male, and 0.9% was unknown.

A single person was responsible for the fatality in 481 cases (88.9%), 2 caregivers were responsible in 51 cases (9.4%), and 3 caregivers were responsible in 3 cases (0.6%). The number of adults responsible was unknown in 6 cases (1.1%). In cases where a single person was responsible for leaving the victim in the car, the caregiver was most commonly identified as the victim's mother (38%), father (32%), or grandparent (6%; Table 2). In 20% of cases, the responsible party was identified as another relative (eg, aunt, uncle, sibling, and cousin) or an alternative caregiver (eg, babysitter and daycare worker).

Most victims (78.2%) were unknowingly left in vehicles by their caregivers, whereas 16.6% of victims were left in vehicles knowingly; it was unknown in 5.2% of cases if the caregiver knowingly or unknowingly left the child in the vehicle. In cases where the victim was knowingly left in the vehicle by the caregiver, the reason why the child was left was unknown 23% of the time. Work or school was documented as the reason the caregiver knowingly left the child in 19% of these cases. In 11% of these cases, the victim was knowingly left in the vehicle because the child was sleeping (Table 3).

Involvement of drugs and/or alcohol by the responsible party was noted in 9.8% of all cases and in 13% of cases in which the child was knowingly left in the vehicle. Criminal charges were filed in 58.2% of all cases and in 98% of cases when drugs and/or alcohol were involved.

TABLE 2. Responsible Individual in Cases That a Single Person Was Accountable

Single Caregiver Responsible	Percentage of Cases
Mother	38
Father	32
Other	20
Grandparent	6
Unknown	4

TABLE 3. Reasons Victims Were Knowingly Left in the Vehicle

Reason Victim Left Knowingly	Percentage of Cases
Other	34
Unknown	23
Work or school	19
Drugs and/or alcohol use	13
Child sleeping	11

Table includes the reasons cited for the 16.6% of victims knowingly left alone in the vehicles. Category "other" includes reasons such as the caregiver needing to run errands.

DISCUSSION

Pediatric fatalities caused by being left in motor vehicles most often occur when caregivers unknowingly leave victims. This cause of mortality in the pediatric population primarily involves infants and toddlers; boys are more commonly involved. A single individual was accountable for leaving the victim alone in a preponderance of cases, and the victim's mother was most often identified as the responsible party. Criminal charges were filed against the individual(s) deemed responsible in more than half of cases. Drugs and alcohol were involved in approximately 10% of cases, of which nearly all had criminal charges filed.

This descriptive study is the largest to examine the circumstances surrounding pediatric heatstroke-related deaths due to being left in motor vehicles. Guard and Gallagher[9] examined a large cohort of heat-related fatalities in the pediatric population in cars identifying 233 deaths in the US and internationally from 1995 to 2002 using news accounts and Internet searches. Booth et al[11] expanded upon this work and examined 231 motor vehicle–related childhood hyperthermia fatalities exclusively in the US from 1999 to 2007. These studies focused on all hyperthermia-related deaths in motor vehicles, including victims left in automobiles and those that had gained access to the motor vehicles on their own. In contrast, our study focuses exclusively on fatalities due to children left in motor vehicles, recognizing that this cohort can be targeted for potential interventions such as education and technological advancements. Furthermore, our study used a single, comprehensive, venerable database to examine this subset of nontraffic motor vehicle–related fatalities.

Our study determined that the mean age of pediatric heatstroke fatalities due to being left in motor vehicles is 16.4 months. Our analysis included all victims ≤14 years of age, but it is important to note that there were only 4 cases in which the victim was ≥5 years old. These isolated fatal cases in older children demonstrate that, although pediatric vehicular heatstroke predominantly affects infants and toddlers, older children are among those vulnerable. The pediatric population is particularly susceptible to hyperthermia-related injuries in stationary automobiles. When compared with adults, children are more susceptible to the effects of elevated temperatures. Tsuzuki-Hayakawa et al[13] demonstrated a significant increase in the temperature of children 9 months to 4.5 years old in comparison to their mothers' when placed in a room that was 35°C (95°F). The authors of this study speculated that the increased body temperature in children was related to their smaller body masses, which were thought to warm more quickly, and their lack of a mature thermoregulatory system.[13]

Prior studies have demonstrated that the interior temperature in a closed, stationary vehicle is significantly higher than the

outside temperature.[14] With an outside ambient temperature of 38.6°C (98.2°F), the interior temperature of a vehicle increases to 51°C to 67°C (124°F–153°F) within 15 minutes of closing the vehicle's doors and windows.[15] Even on days with moderate ambient temperatures (22°C/72°F), the interior temperature of a stationary vehicle may reach 47°C (117°F) within 60 minutes.[16] Our study supports this notion that even moderate climates are dangerous to children left in stationary vehicles. Although most heatstroke deaths occurred with ambient temperatures higher than 80°F, the ambient temperature was less than 80°F in 10.2% of cases.

The elapsed mean time from when the child was left in the car to the time when discovered was estimated at 296 (±208) minutes in our study. This is not reflective of the amount of time for the child to succumb to the effects of heatstroke, and we hypothesize that this duration of time would, in fact, be much shorter. This is supported by Grundstein et al,[17] who used a heat balance model to evaluate a simulated infant's core temperature in response to hot cars. Their study demonstrated that during the summer months, hyperthermia can be reached within 20 minutes and demise can occur within approximately 2 hours.[17] Thus, there is a narrow window of time to rectify the misstep before there is morbidity or mortality.

In examining the reasoning behind these fatalities, our study found that most heatstroke-related deaths resulted from unknowingly leaving the victim in the vehicle (78.2%). This aligns with the study by Booth et al[11] in which the child was unknowingly left in the vehicle in 75.5% of cases; the most common circumstances cited in their study surrounding these hyperthermia fatalities include the child being forgotten in the vehicle (24.2%) and forgetting to drop the child off at daycare/babysitter (19%). The NHTSA and KAC suggest that caregivers "Look before you lock" and consider placing a phone, briefcase, or handbag in the back seat when traveling with a child to prevent these fatalities.[18,19] These tips may be helpful and education of caregivers on the risk of hot cars is very important. However, education alone will not eliminate all deaths related to children left in hot cars. Many well-meaning, well-educated caretakers simply lose awareness that the child is in the car, especially if their routine has changed (eg, they do not usually drop the child off at daycare). New technology implementation is essential to reduce deaths from hot cars. Much research has been done to develop rear seat reminder systems that will alarm when a child is left in a vehicle.[20,21] Hopefully, technological advancements will lead to a stark decrease in these potentially avoidable fatalities.

In a survey study completed by Roberts and Roberts,[14] 24% of mothers admitted to leaving a child in a stationary car. In examining the subgroup of victims left in vehicles, Guard and Gallagher[9] and Booth et al[11] found that in 27% and 13% of cases, respectively, victims were intentionally left in the automobile. Our study demonstrated a similar proportion of fatal cases resulting from knowingly leaving the child in the car (16.6%). Common reasons cited in our cohort for leaving the child unattended included the caregiver's need to attend work/school or the desire to allow the child to continue sleeping. This suggests that public awareness campaigns are needed and pediatricians should continue to educate caregivers on the dangers of intentionally leaving children in the car for any reason, including allowing them to sleep.

The increase in pediatric heatstroke fatalities has coincided with movement of children to the back seat of the car for protection from threats posed due to being a front seat passenger, such as air bags.[22] Although being properly restrained in the back seat is the safest place for children to protect them from morbidity and mortality associated with traffic accidents, this position in the car likely increases the chance of being unknowingly left. Furthermore, rear facing car seats may have compounded the problem, making it difficult for a caregiver to visualize a sleeping child. Additional work is required to assure the safety of children in vehicles and to prevent this potentially avoidable cause of pediatric death.

There are several limitations to this study. Although the KAC database offers one of the most comprehensive data sets recording motor vehicle related heatstroke deaths, it is possible that cases were missed in our study. KidsAndCars.org relies on systematic review of media reports, Internet searches, and reports from law enforcement to collect cases. The database provided by KAC is constantly evolving as additional data becomes available, and it is possible that additional cases or data elements have been collected since the analysis was performed. Zonfrillo et al[10] used the KAC database to look at nontraffic-related motor vehicle injuries and fatalities including those related to heatstroke, trunk entrapment, power window accidents/strangulation, frontovers, and backovers, noting that the data set might have missed cases of minor injuries or near misses on account of these events failing to capture the attention of the media. Conversely, our study only examined fatal cases due to heatstroke, which may be more likely to have been covered in these reports. Our study reports fewer fatalities per year due to heatstroke when compared with prior studies (Guard and Gallagher,[9] 33.2 per year; Booth et al.[11] 28.8 per year). This is likely because our study excluded children who gained access to vehicles on their own.

In review of the data, it is clear that the incidence of pediatric fatalities due to being left in motor vehicles has increased over the course of the 26-year study period. It is important to note that the data from 1990 to 1995 were collected retrospectively by KAC, and as a result, this may have contributed to the decreased number of cases during that initial 5-year period (2–13 cases per year). Comparatively, the data that was collected prospectively from 1996 to 2016 is much more robust, with approximately 8 to 31 cases per year. When analyzing the data during this 26-year period, there was an average of 21.3 deaths per year, which is likely skewed because of selection bias in collecting data in the early 1990s. Furthermore, the ability to perform Internet searches and the utilization of Google alerts by KAC likely account for the larger number of cases identified in recent years, which is likely more reflective of the magnitude of this issue with an estimated 28.1 annual deaths per year since 2000.

CONCLUSIONS

Pediatric heatstroke due to being left in motor vehicles is a significant and potentially avoidable cause of death in the pediatric population. Prior studies have called for advocacy for this vulnerable patient population in the form of education, technological innovation, and industry regulation.[9] However, pediatric heatstroke deaths continue to occur when caregivers knowingly and unknowingly leave children in cars. Advancement and implementation of technological interventions along with targeted educational campaigns remain necessary to eliminate this potentially avoidable cause of pediatric mortality.

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