Environmental Deaths in Southern Arizona

Kevin M. Lougee, Gregory L. Hess, David C. Winston

ABSTRACT

Introduction: The Pima County Office of the Medical Examiner (PCOME) maintains medicolegal jurisdiction over Southern Arizona, which includes the Sonoran Desert and the Arizona/Mexico border. Given the unique climate and biodiversity of the Sonoran Desert coupled with the Mexican border, environmental-related deaths are represented in proportions different from other jurisdictions in the United States.

Methods: A retrospective study of deaths falling into one of five categories (hyperthermia, hypothermia, undetermined with skeletal and/or mummified modifiers, venom-related, and lightning) certified by the PCOME between January 1, 2010 and December 1, 2017 was conducted by searching the PCOME electronic database.

Results and Discussion: Of the 16 649 cases certified by the office during that time, 639 were categorized into one of the above five categories. Hyperthermia cases were the most common, followed by undetermined, hypothermia, venom-related, and lightning. A unique population of individuals referred to as undocumented border crossers (UBCs) is discussed and accounted for 470 of the 639 deaths. *Acad Forensic Pathol.* 2018 8(1): 50-63

AUTHORS

Kevin M. Lougee DO, Pima County Office of the Medical Examiner

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, principal investigator of the current study.

Gregory L. Hess MD, Pima County Office of the Medical Examiner

Roles: Project conception and/or design, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work, writing assistance and/or technical editing.

David C. Winston MD PhD, Pima County Office of the Medical Examiner

Roles: Project conception and/or design, manuscript creation and/or revision, approved final version for publication, accountable for all aspects of the work, writing assistance and/or technical editing.

CORRESPONDENCE

Kevin M. Lougee DO, 2825 E. District Street, Tucson AZ 85714, Kevin.Lougee@pima.gov

ETHICAL APPROVAL

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

STATEMENT OF HUMAN AND ANIMAL RIGHTS

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

STATEMENT OF INFORMED CONSENT

No identifiable personal data were presented in this manuscript

DISCLOSURES & DECLARATION OF CONFLICTS OF INTEREST

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

FINANCIAL DISCLOSURE

The authors have indicated that they do not have financial relationships to disclose that are relevant to this manuscript

KEYWORDS

Forensic pathology, Southern Arizona, Hyperthermia, Hypothermia, Envenomation, Lightning

INFORMATION

ACADEMIC FORENSIC PATHOLOGY: THE OFFICIAL PUBLICATION OF THE NATIONAL ASSOCIATION OF MEDICAL EXAMINERS

©2018 Academic Forensic Pathology International • (ISSN: 1925-3621) • <https://doi.org/10.23907/2018.004>

Submitted for consideration on 8 Dec 2017. Accepted for publication on 18 Jan 2018

INTRODUCTION

Southern Arizona is considered the portion of Arizona south of the Gila River and encompasses all of Pima, Cochise, and Santa Cruz counties, along with portions of Yuma, Maricopa, Pinal, Graham, and Greenlee counties (**Figure 1**). The Pima County Office of the Medical Examiner (PCOME) located in Tucson, Arizona maintains medicolegal jurisdiction over Pima, Cochise, and Santa Cruz counties, corresponding to a population of approximately 1.2 million people (1). The PCOME also completes contract case work for Yuma, Pinal, Graham, and Greenlee counties. The average number of annual cases reported to the PCOME from 2010-2016 was 2963, with a yearly average of 1412 full autopsies and 402 external examinations. Owing to the unique characteristics of the Sonoran Desert, along with the close proximity to the Mexican border, the PCOME encounters a variety of environmental-related deaths at a proportion different from other regions of the United States. The most common causes of environmental-related deaths are hyperthermia, hypothermia, lightning, and envenomation.

A large portion of Southern Arizona falls within the Sonoran Desert, which is a 100 000 square mile (259 000 square kilometer) North American desert that covers parts of the southwestern United States and northwestern Mexico (2). The Sonoran Desert is the hottest of the Northern American deserts, with record high temperatures ranging from 88°F (31°C) in December to 117°F (47°C) in June (3). The Sonoran Desert has a distinct bimodal precipitation pattern of violent summer monsoon thunderstorms followed by low intensity winter rains that help to create a wide variety of biological diversity (4). In the winter, low temperatures average 41°F (5°C), but overnight freezing conditions do regularly occur. Tucson's record low temperature during the winter was reported to be 6°F (-14°C) (3). Southern Arizona mountain ranges rise to 9000 feet (2743 m) elevation and temperatures can routinely drop below freezing in the winter months at these altitudes.

A population of individuals unique to the PCOME are undocumented border crossers (UBCs). The term UBCs was developed by the PCOME to describe sus-

pected migrants from Mexico and Central America who died during an attempt to enter the United States in an undocumented manner. This designation provided a mechanism for the office to track these remains separately for statistical purposes (5). This subset of individuals contributed significantly to the exposure-related deaths, especially hyperthermia.

METHODS

A retrospective study of deaths falling into one of five categories (hyperthermia, hypothermia, undetermined with skeletal and/or mummified modifiers, venom-related, and lightning) certified by the PCOME between January 1, 2010 and December 1, 2017 was conducted by searching the PCOME electronic database.

RESULTS AND DISCUSSION

Between January 1, 2010 and December 1, 2017, the PCOME examined a total of 639 environmental-related deaths. Of these deaths, hyperthermia was the most common while lightning the least common (**Figure 2**). Included in **Figure 2** is a group of 152 decedents for whom the cause of death was classified as undetermined because the remains were too decomposed to definitively determine a cause of death. Of these undetermined deaths, 141 were designated as UBCs. Nineteen have been positively identified by DNA. The age range for the identified UBCs was 21 to 49 years (mean 31.4 years and median 30 years). The sex breakdown for all was 138 males, 8 females, and 6 undetermined due to the absence of sex indicating skeletal elements. Given the condition of the body, inadequate investigation due to the prolonged interval between death and discovery of the remains, and that approximately 93% of these cases were UBCs, these cases are best classified as undetermined, despite the fact that many of them were likely exposure-related.

Hyperthermia

Hyperthermia is defined as having a core body temperature above 100.9°F (38.3°C); however, death generally does not occur until higher temperatures are reached, usually greater than 105°F (40.6°C) (6). In hyperther-

Figure 1: A county map of Arizona showing the fifteen counties along with color designations for the counties that the Pima County Office of the Medical Examiner (PCOME) is the medical examiner for and also those the PCOME does contract services for on an as needed basis. Southern Arizona is considered the portion of Arizona south of the Gila River, and is the focus of this paper. Map adapted from d-maps.com, map: Arizona, http://d-maps.com/carte.php?num_car=19653&lang=en.

mia deaths, as in all environmental deaths, the investigation into the circumstances surrounding the death are of utmost importance. Varying stages of decomposition from minor skin slippage to full skeletonization are often observed (**Image 1**) as a result of accelerated decomposition in the setting of high temperatures. The typical UBC dying of hyperthermia is found in a remote desert area with some degree of decomposition change and with personal effects such as water containers, backpack, toiletry items, extra clothing, and food (**Image 2**). There are no specific autopsy findings for hyperthermia, although vitreous electrolytes (if available) can be analyzed for a dehydration pattern.

In the ideal situation, a perimortem core body temperature is obtained along with a complete autopsy including toxicology to rule out lethal injury, natural disease, or drug toxicity. Obtaining a perimortem core body temperature is not practicable in the vast majority of the cases examined at the PCOME given that most individuals are found hours to days after death in the desert with decomposition in progress. When the perimortem core body temperature is not available, the circumstances of death support exposure, and there are no autopsy or toxicologic causes of death, the diagnosis of hyperthermia is rendered. Most of the population of Southern Arizona is acclimated to liv-

Figure 2: Types of environmental deaths certified at the Pima County Office of the Medical Examiner (2010-present).

ing in a climate with higher temperatures. As a result, the majority of the hyperthermia deaths diagnosed at the PCOME are not the typical heat wave associated deaths (e.g., extremes of age or those taking medications that impair the body's ability to eliminate heat), but rather younger, healthy individuals with prolonged exposure to excessive heat. On occasion, the office does see summer visitors who are not used to the dry, hot environment of the desert, attempt outdoor activities such as hiking, and succumb during exertion.

Given the average summer high temperature of 99°F (37.2°C) in Tucson, and often greater than 100°F (37.8°C), with a record high of 117°F (47.2°C), it is not surprising that hyperthermia deaths are the

most common environment-related death seen by the PCOME. Since 2010, the office has recorded 386 hyperthermia deaths, with UBCs representing 77% of these deaths (**Figure 3**). The age range for all hyperthermia deaths was 7 months to 94 years (mean 37.2 years and median 33.5 years) with a male to female ratio of 5:1. The age range for the 299 UBCs was 15 to 60 years (mean 31.7 years and median 30 years) with a male to female ratio of 8.6:1, while the age range for the 87 non-UBCs was 7 months to 94 years (mean 53.9 years and median 56 years) with a male to female ratio of 1.6:1. When comparing UBC to non-UBC related hyperthermia deaths, one can see that although male deaths are more common in both groups, the male to female ratio is over three times higher in the

Image 1: Skeletal remains of a 36-year-old undocumented border crosser found in the desert along a frequently traveled migrant path.

UBC group. In addition, the UBC group had a lower mean and median age by 22.2 years and 26 years, respectively when compared to the non-UBC group.

Thirty-four of 386 hyperthermia cases had contributing medical conditions, with 30 of them being in the non-UBC group. Three of the total number of hyperthermia deaths included drug intoxication and four had ethanol intoxication. The drugs- and ethanol-related deaths were all in the non-UBC population. Two of the hyperthermia deaths involved children (7 months and 2 years) who were found in an enclosed vehicle and one case involved a schizophrenic inmate on psychotropic medications being transported to Tucson on a correctional facility bus with nonfunctioning air conditioning.

The manner of death was ruled accident for all but one of the cases, which was ruled suicide. A 53-year-old male was found deceased in his car in July with two empty bottles of vodka and suicide text messages on his phone. His toxicology was positive for an ethanol concentration of 0.241% (w/v) in the heart blood and 0.165% (w/v) in the vitreous fluid. There was no reported history of chronic ethanol abuse; however, he did have hepatic steatosis on microscopic examination. Given these findings, coupled with the fact that he was found in a hot car in July, his cause of death was ruled as the combined effects of probable hyperthermia and alcohol intoxication.

Image 2: A 21-year-old undocumented border crosser with typical clothing and water jugs.

Hypothermia

Hypothermia is defined as having a core body temperature below 95°F (35°C); however, death generally does not occur until lower temperatures are reached, often into the upper 70s or low 80s, when death is usually the result of ventricular fibrillation (7). Hypothermic deaths are broadly classified into two categories: dry (those occurring on land) and wet (those occurring in the water) (7). Those individuals exposed to wet hypothermia generally die more quickly than those exposed to dry hypothermia since heat loss is much more rapid in water than in air. There are no pathognomonic findings for hypothermia, thus a thor-

ough investigation is necessary since hypothermia is a diagnosis of exclusion. The autopsy is essential to rule out injury and/or natural disease. Some nonspecific findings commonly observed in hypothermic deaths include purple patches of skin often over the extremities, Wischnewsky spots of the stomach mucosa (**Image 3**), and hemorrhage of the pancreas.

Given the average low winter temperatures in Southern Arizona are in the low 40s, the PCOME does not see as many hypothermia deaths as compared to hyperthermia deaths (3). In the higher elevations, temperatures can drop into the single digits a few nights each year. The office has certified 81 hypothermia

Figure 3: Hyperthermia deaths certified at the Pima County Office of the Medical Examiner (2010-present).
UBC - undocumented border crosser

deaths since 2010, with 27 being UBCs (**Figure 4**). The age range was 15 to 88 years (mean 49.4 years and median 47 years), with a male to female ratio of 4.8:1. Approximately 26% of the non-UBC hypothermia cases had ethanol intoxication listed as a contributing factor, supporting the trend commonly seen in the literature (8). None of the UBC hypothermia deaths had ethanol as a contributing factor. No over-the-counter, prescribed, or illicit drugs were determined to have contributed to the hypothermia deaths. It was also determined that 28% of the total hyperthermia cases had contributing medical conditions with atherosclerosis, hypertension, dementia, and chronic obstructive pulmonary disease as the most common diseases reported. All but one case with contributing medical conditions was in the non-UBC group. The one UBC with a contributing medical condition was a 39-year-old male with coronary artery atherosclerosis.

The manner of death for 79 of the 81 cases was accident. One case was ruled suicide since the deceased was found nude from the waist down outside in a mountainous area away from his home and a suicide note was found in his car a short distance away from his body. A full autopsy revealed moderate atherosclerotic heart disease with negative toxicology and no significant injuries. Given that overnight temperatures were reported to be below freezing, his death was ruled probable hypothermia. The other nonaccident case involved a 47-year-old male with a history of chronic ethanol abuse and a seizure condition who was found behind a liquor store where overnight temperatures were reported to be as low as 21°F (-6°C). The cause of death was probable hypothermia with chronic ethanol abuse and a seizure disorder as other significant contributing conditions. The manner of death was ruled undetermined because the seizure disorder was possibly the result of a remote assault.

Image 3: Wischnowsky spots on the gastric mucosa of an individual who died of hypothermia.

Venom-Related

Venom-related deaths result from either allergic or toxic reactions from stings or bites from a variety of insects (Hymenoptera species), arachnids, and reptiles. An allergic reaction resulting in fatal anaphylaxis requires previous sensitization to the toxin and can result from a single sting, while toxic reactions are the result of massive envenomation when an individual receives several hundred stings causing a lethal dose of venom to be injected (**Image 4**). Anaphylactic deaths are more common than massive envenomation deaths (9). As is the case in with all environmental deaths, investigative circumstances are integral to making the correct diagnosis, especially in anaphylaxis cases when witnesses or the family are not aware of an allergy.

It is estimated that there are as many as 1000 species of bees in the Sonoran Desert (10). It is thought that this region of the United States has more kinds of bees than anywhere else in the world, with the possible exception of desert areas in Israel (10). The Southern Arizona bee population includes the well-publicized Africanized honey bee ("killer bees") that were first documented in Arizona in 1993 and are currently found all over the state (11). The difference between Africanized honey bees and a typical honey bee is that the Africanized bees are more easily provoked, quicker to swarm, attack in greater numbers, and pursue victims at greater distances than a typical honey bee, creating a potentially dangerous situation for an individual who encounters them (11).

Figure 4: Hypothermia deaths certified at the Pima County Office of the Medical Examiner (2010-present).
UBC - undocumented border crosser

Since 2010, the PCOME has had a total of 15 Hymenoptera-related deaths. Twelve of these deaths were certified as envenomation and the other three as anaphylaxis (**Figure 5**). None of the bees were collected at the envenomation deaths scenes, but due to the numerous cutaneous stings observed at autopsy, the most likely bee was the Africanized honey bee. The age range for all Hymenoptera-related deaths was 7 to 75 years (mean of 50 years and median of 48 years), with 14 males and 1 female. Three of the 12 envenomation cases had contributing natural disease listed on the death certificate (two with atherosclerotic heart disease and one with metastatic pancreatic cancer). Two of the cases were UBCs traveling by foot through the desert. Of the three anaphylactic deaths, only one

had a documented history of a severe allergy to bees. Although anaphylactic deaths are documented to be more common than massive envenomation deaths, the PCOME has experienced the opposite during the reported period. The manner of death for all 15 cases was accident.

Only one case was thought to be possibly due to a snake bite. A 33-year-old female UBC found decomposing in the desert was reportedly bitten by a snake while traveling by foot with a group of UBCs. She could not keep up with the group and was left behind. Due to extensive decomposition including dark discoloration of the skin, superficial skin separation, tissue loss, and focal mummification, the alleged snake

Image 4: A 38-year-old undocumented border crosser found with extensive bee stings, many still with the stingers.

bite site could not be identified. Furthermore, no one in her travelling group could confirm that it was a venomous snake. The cause of death was certified as undetermined with snake bite and/or hyperthermia due to exposure as contributing conditions. No deaths due to Gila monster, black widow, or scorpion bites have been certified by this office during the reported period.

Lightning

Lightning-related deaths are caused by a high voltage direct current in the kiloampere range that either strikes an individual directly or via a side-flash (when lightning strikes an object and ricochets to a nearby victim) or conducted through an intermediary object (12). The mechanism of death in most lightning-related deaths is usually the result of either a cardiac or

neurologic event. These deaths are often unwitnessed and rely heavily on investigative information and autopsy findings. Investigative findings at the scene that suggest lightning may be the cause of death include finding an individual deceased outside especially after a storm, clothing and shoes torn apart and/or at a distance from the body, and burned or melted metal objects and electronics carried by the deceased (**Images 5 and 6**). Autopsy findings observed in lightning-related deaths include cutaneous thermal injuries of varying degrees (**Image 7**), singed body hair (**Image 8**), burn marks on the skin corresponding to metal portions of clothing or jewelry, Lichtenberg figures on the skin, and ruptured tympanic membranes. The National Lightning Detection Network (NLDN) can be utilized in suspected cases of a lightning strike that is not witnessed or who do not have other supportive

Figure 5: Hymenoptera deaths certified at the Pima County Office of the Medical Examiner (2010-present).
UBC - undocumented border crosser

Image 5: Personal effects of an individual struck by lightning showing burns on a coin and damage to a cell phone.

information or examination findings. The NLDN is a network of over 100 remote, ground-based lightning sensors that instantaneously detect every lightning strike in the United States (13). These sensors send information to a control center located in Tucson, Arizona (13).

Arizona averages over 600 000 lightning strikes per year with the great majority of those occurring during the monsoon season (14). Arizona's monsoon season runs from June 15th through September 30th, and is caused by the combination of increased moisture in the air as a result of warm air creating surface low pressure and the shift in wind currents (15). This combination of events results in thunderstorms with heavy rainfall. These violent storms often begin quickly with little to no warning and can be of short duration, leaving those individual caught outdoors during the onset at risk of not only being struck by lightning but also being a victim of flash flooding.

To date, there have been 214 reported lightning deaths in the US since 2010 (16), and the PCOME has recorded five (**Table 1**). The manner of death for all five

Image 6: A pocket knife carried by an individual struck by lightning showing burns and melting of the metal.

cases was accident. Of these five deaths, four were males and one was female, ranging in age from 9 to 53 years. One of the males was a UBC from Mexico who was traveling by foot through the Arizona desert with his father in late July when a monsoon storm quickly developed and he was reportedly struck. All five lightning-related deaths at the PCOME occurred between June 30th and August 14th, which coincides

Image 7: Thermal burns of a 33-year-old male struck by lightning.

Image 8: Close-up of Image 7 showing singed body hair.

Table 1: Lightning Deaths Certified at the Pima County Office of the Medical Examiner (2010-present)

Month and Year	Age	Sex	Witnessed	Circumstances
July 2015	9	F	Yes	Directly struck while outside in Mexico then transported to hospital in Tucson, Arizona
June 2015	33	M	No	Found on dirt road with pants down and burns chest, groin, and legs
August 2014	27	M	Yes	Directly struck while using weed trimmer on school field
July 2014	16	M	Yes	Undocumented border crosser from Mexico traveling through Arizona desert by foot directly struck during storm
July 2010	53	M	Yes	Directly struck while on golf course

with Arizona monsoon season. The literature reports that most lightning-related deaths are unwitnessed; however, 80% of the PCOMEs lightning cases were witnessed (17).

CONCLUSION

The unique climate and biological diversity of the Sonoran Desert coupled with the close proximity to the Arizona/Mexico border makes the environmental-related deaths investigated by the PCOME significantly different from most other jurisdictions in the United States. This is most dramatically seen in the hyperthermia cases. The need for accurate and thorough investigative information is of utmost importance when faced with any environmental death, as the cause of death may rely solely on circumstantial evidence, especially in the absence of significant autopsy findings.

REFERENCES

- 1) United States Census Bureau [Internet]. Washington: US Department of Commerce; c2017. Quickfacts: Pima County, Arizona; 2016 Jul 1 [cited 2017 Nov 28]. Available from: <https://www.census.gov/quickfacts/fact/table/pimacountyarizona/LND110210>.
- 2) DesertUSA [Internet]. Escondido (CA): DesertUSA and Digital West Media, Inc.; c1996-2017. Sonoran Desert; [cited 2017 Nov 28]. Available from: <https://www.desertusa.com/sonoran-desert.html>.
- 3) The Weather Channel [Internet]. Atlanta: The Weather Company, LLC; c2017. Tucson, AZ monthly weather; [cited 2017 Nov 28]. Available from: <https://weather.com/weather/monthly/l/USAZ0247:1:US>.
- 4) National Park Service [Internet]. Washington: US Department of the Interior; c2017. Sonoran Desert network ecosystems; [cited 2017 Nov 28]. Available from: <https://science.nature.nps.gov/im/units/sodn/sonoran.cfm>.
- 5) Anderson BE, Parks BO. Symposium on border crossing deaths: introduction. *J Forensic Sci*. 2008 Jan; 53(1):6-7. PMID: 18279231. <https://doi.org/10.1111/j.1556-4029.2007.00608.x>.
- 6) Donoghue ER, Graham MA, Jentzen JM, et al. 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 Mar; 18(1):11-4. PMID: 9095294. <https://doi.org/10.1097/00000433-199703000-00002>.
- 7) DiMaio VJ, DiMaio D. Forensic pathology. 2nd ed. Boca Raton: CRC Press; 2001. Chapter 17, Hyperthermia and hypothermia: the effects of heat and cold; p. 422-32.
- 8) Taylor AJ, McGwin G Jr, Davis GG, et al. Hypothermia deaths in Jefferson County, Alabama. *Inj Prev*. 2001 Jun; 7(2):141-5. PMID: 11428562. PMCID: PMC1730727. <https://doi.org/10.1136/ip.7.2.141>.
- 9) Dolinak D, Matshes E, Lew E. Hymenoptera and venom-related deaths. In: Forensic pathology: principles and practice. 1st ed. San Diego: Elsevier Academic Press; 2005. p. 255.
- 10) Buchmann SL. Arizona-Sonora Desert Museum [Internet]. Tucson: Arizona-Sonora Desert Museum; c2017. Bees; [cited 2017 Nov 29]. Available from: https://www.desertmuseum.org/books/nhsd_bees.php.
- 11) Gouge DH, Olson C, Rehm-Bowler M, et al. Bee management [Internet]. Tucson: University of Arizona and Arizona Department of Environmental Quality; 2017 [cited 2017 Nov 29]. 3 p. Available from: <https://cals.arizona.edu/urbanipm/buglist/bees.pdf>.
- 12) DiMaio VJ, DiMaio D. Lightning. In: Forensic pathology. 2nd ed. Boca Raton: CRC Press; 2001. p 415-7.
- 13) NASA Global change master directory [Internet]. Washington: National Aeronautics and Space Administration; US national lightning detection network database (NLDN); [cited 2017 Nov 30]. Available from: https://gcmd.nasa.gov/records/GCMD_NLDN.html.
- 14) Crimmins M. Shocking facts about Arizona lightning [Internet]. Tucson: Department of Soil, Water, and Environmental Science, University of Arizona; 2017 [cited 2017 Nov 30]. 1 p. Available from: <https://cals.arizona.edu/backyards/sites/cals.arizona.edu/backyards/files/p16.pdf>.
- 15) The Arizona experience [Internet]. The Arizona Experience; c2017. Arizona's monsoon season; [cited 2017 Nov 30]. Available from: <http://arizonaexperience.org/land/arizonas-monsoon-season>.
- 16) National Weather Service [Internet]. Washington: US Department of Commerce; c2017. US lightning fatalities 2007-2017; [cited 2017 Nov 30]. Available from: <http://www.lightningsafety.noaa.gov/fatalities.shtml>.
- 17) Dolinak D, Matshes E, Lew E. Lightning strike. In: Forensic pathology: principles and practice. 1st ed. San Diego: Elsevier Academic Press; 2005. p. 252.