

## A 5-Year Review of Pavement Burns From a Desert Burn Center

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Pavement burns account for significant burn-related injuries in the Southwestern United States and other hot climates with nearly continuous sunlight and daily maximum temperatures above 100°F. At peak temperatures, pavement can be hot enough to cause second-degree burns in a matter of seconds. The goal of this study was to review pavement burn injury admissions at a desert burn center compared with maximum ambient temperatures to determine which temperatures correlated to an increase in burn admissions. We obtained ambient temperature data from the National Oceanic and Atmospheric Administration. We reviewed our registry for 5 years retrospectively of all pavement burn injury admissions to our burn center. A total of 173 pavement-related burn cases were identified. We demonstrated an exponential increase in the rate of burn admissions as maximum ambient temperatures increased. More than 88% of pavement-related burn injury admissions occurred when the ambient temperature reached 95°F or higher. The risk per day was extrapolated based on the number of pavement burn injury admissions and the number of days at each of the maximum ambient temperatures recorded. The risk of pavement burns in areas of direct sunlight begins around 95°F and increases exponentially as ambient temperatures rise. This information will be used for burn outreach prevention and public health awareness programs. The benefit of this study relates to the entire community since high ambient temperatures put everyone at risk for hot pavement burns.

The mechanism for most burn injuries is by flame and scalding liquid, which results in thermal injury and coagulative necrosis of the epidermis and underlying tissues.<sup>1</sup> However, in the Southwestern United States and other hot climates with nearly continuous sunlight and daily summer temperatures over 100°F, pavement burns account for a significant number of burn-related injuries.<sup>2</sup> Pavement absorbs radiant energy and is significantly hotter than ambient temperatures when in continuous direct sunlight.<sup>2</sup> Clifton et al<sup>3</sup> recorded pavement temperatures well above 64°C (147°F) when the ambient temperature reached 43.9°C (111°F). At these temperatures, hot pavement can cause second- and third-degree burns in seconds.

Patients at particular risk include children who are unaware of the hot pavement, diabetics with peripheral neuropathy who do not feel the significant heat, patients who become unconscious due to medical reasons, such as seizures, strokes, or intoxication, or trauma victims who are incapacitated on the ground.<sup>3-5</sup> As such, many patients suffering from pavement burns have concomitant medical or traumatic issues. Furthermore, pavement burns can cause significant morbidity compared with similarly sized percentage total body surface area (%TBSA) scald or flame burns and have been shown to

increase the length of stay (LOS), total hospital costs, and the need for operative debridement when compared with other etiologies.<sup>6</sup> The goal of this study is to review pavement burn injury admissions at a desert burn center and compare to ambient temperature to determine which temperatures result in burn admissions. This knowledge will facilitate public health initiatives and improved awareness of pavement burn risk to the general public.

### METHODS

We retrospectively reviewed the registry at our ABA-verified Burn Center for all burn admissions during the 5-year period 2013 to 2017. The total number of pavement burn injury admissions was identified. We recorded the date of injury for each burn admission. Both isolated pavement burns and pavement burns accompanied by another burn or injury mechanism were included. Patient identifiers were not used during this review. This project was exempted from review by our Institutional Review Board.

The data collected from our registry included the following: date of admission, burn mechanism, and %TBSA. We obtained the daily average and maximum ambient temperature data from the National Centers for Environmental Information section of National Oceanic and Atmospheric Administration (NOAA) for the selected time periods.<sup>7</sup> The number of pavement burn patients admitted were plotted against each daily maximum temperature. To identify the risk per day, the number of pavement burn injury admissions was divided by the number of days at each maximum ambient temperature, yielding a rate of burn admissions for each max temperature. We used weighted averaging for a

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clearer view of our daily rate data, fit to an exponential trend-line. We assigned risk categories based on ambient temperature threshold and the number of pavement burn injury admissions per day at each maximum temperature. The risk categories were assigned as baseline/low, moderate, high, very high, extreme.

## RESULTS

A total of 173 pavement-related burn injury cases were identified in this 5-year period. We found that 149 of these cases were isolated pavement burn injuries. The remaining 24 cases involved pavement burns plus another mechanism of burn-related injury, such as friction burns from motor vehicle crashes, auto versus pedestrian injuries, or other mechanism. Using the data from NOAA, the maximum ambient temperature value for each day of each pavement burn injury admission was obtained. The average number of days per year at each daily maximum atmospheric temperature is seen in Figure 1. The %TBSA was available for 165 out of 173 patients. The average %TBSA was 7.7%, and the median 6%. The highest %TBSA recorded was 38%, which occurred when the maximum ambient temperature was 106°F. The majority of pavement burn injury admissions (153 out of 173, 88%), occurred when the maximum ambient temperature was 95°F or higher. The number of pavement burn admissions at or

above other maximum ambient temperature values was as follows: 147 at or above 100°F, 114 at or above 105°F, 52 at or above 110°F, and 12 at or above 115°F. The maximum ambient temperature recorded for a burn admission was 117°F (Figure 2).

Figure 3 shows the risk of pavement burn injuries per day, which resulted from dividing the number of pavement burn admissions by the number of days at each maximum ambient temperature. We found a baseline risk below 95°F and an increasing risk as maximum ambient temperature increased. We were able to demonstrate an exponential increased risk of burn admission as maximum temperature increased using a weighted average, fit to an exponential trend-line (Figure 4). There is a higher number of pavement burns with higher atmospheric temperatures and a significant increase in these numbers at temperatures above 95°F. Based upon these findings, we stratified the following temperatures with an associated risk description—below 95°F: baseline/low risk; 95–105°F: moderate risk; 105–110°F: high risk; 110–115°F: very high risk; 115°F and higher: extreme risk.

## DISCUSSION

Pavement burns account for a significant number of burn-related injuries, particularly in the Southwestern United

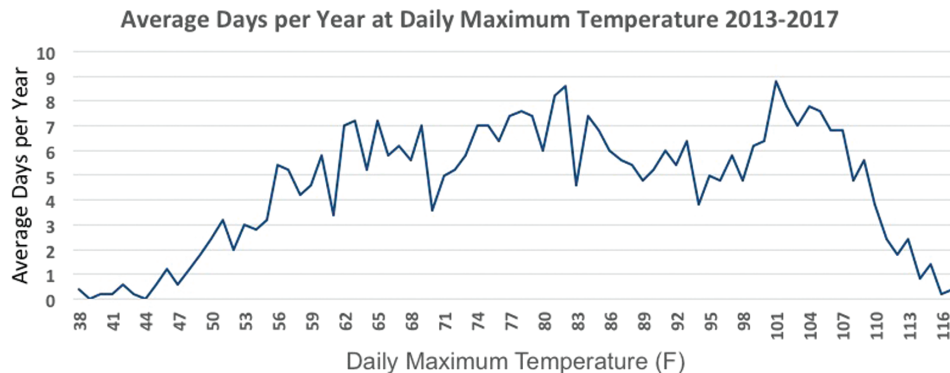


Figure 1. The average number of days per year at daily maximum ambient temperature recorded.

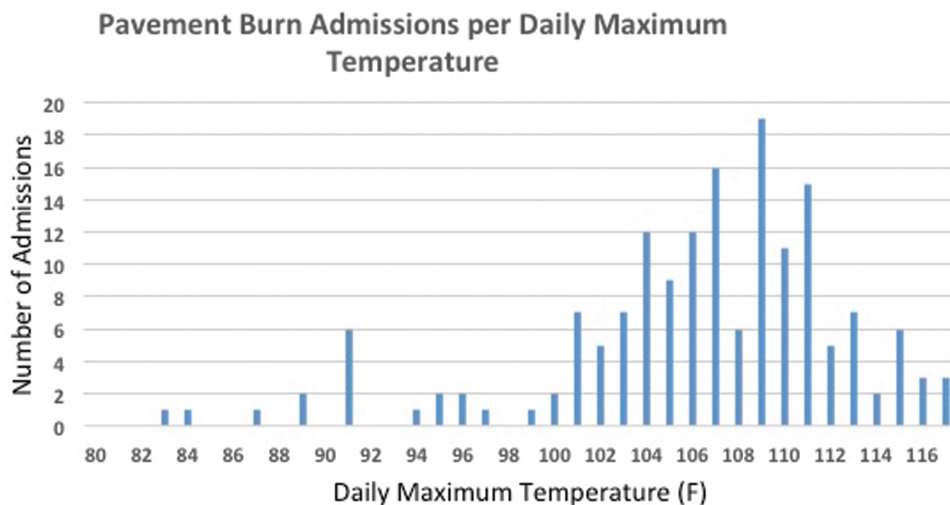


Figure 2. A number of pavement burn admissions per daily maximum ambient temperature.

States. The pavement can be significantly hotter than the ambient temperature in direct sunlight and can cause second-degree burns within 2 seconds.<sup>2</sup> Victims of motor vehicle collisions, pedestrians and cyclists struck by motor vehicles, and patients suffering ground level falls can all be at risk for pavement burn injury.<sup>4</sup> Our regional burn center is affiliated with a level 1 Trauma Center, and we see a number of pavement burn injury admissions throughout the year, especially during the hotter summer months. These patients include those who did not realize the pavement was hot until it was too late, such as children and confused persons. Other patients with neurologic impairment such as diabetics are also affected. Patients who are mentally or physically incapacitated and lie on the pavement for a period of time, such as patients suffering from seizure, stroke, trauma, and/or drug intoxication (Figures 5 and 6). Pham et al<sup>8</sup> reviewed data from the National Burn Repository between 1991 and 2005 and found that 14% of burn unit admissions are older adult patients. Additionally, age, %TBSA burn, and percent of full-thickness injury were found to be independently associated with increased mortality risk.<sup>8</sup> They also found that burns in higher age categories were

associated with increased LOS per %TBSA, as well as increased hospital charges.<sup>8</sup>

Higher %TBSA has been shown to be associated with higher mortality in burn patients.<sup>9</sup> Pavement burn injuries, when compared with other burn etiologies of similar surface area, tend to result in higher morbidity and mortality. The average and median %TBSA in our pavement burn admissions was 7.7% and 6%, respectively. The highest %TBSA was 38%, and this admission occurred when the maximum ambient temperature was 106°F. This information is useful for all burn centers located in hotter climates, to plan and prepare for the coordination of care and treatment for pavement burn patients, particularly during the summer months. Early excision and grafting has been demonstrated to help improve mortality and morbidity in these specific burn patients.<sup>9</sup>

We found that the risk for pavement burn injuries in the desert begins around 95°F and increases exponentially as the temperature rises. More than 88% of our pavement burn admissions occurred at or above this maximum ambient temperature. We attributed a low/baseline risk of pavement

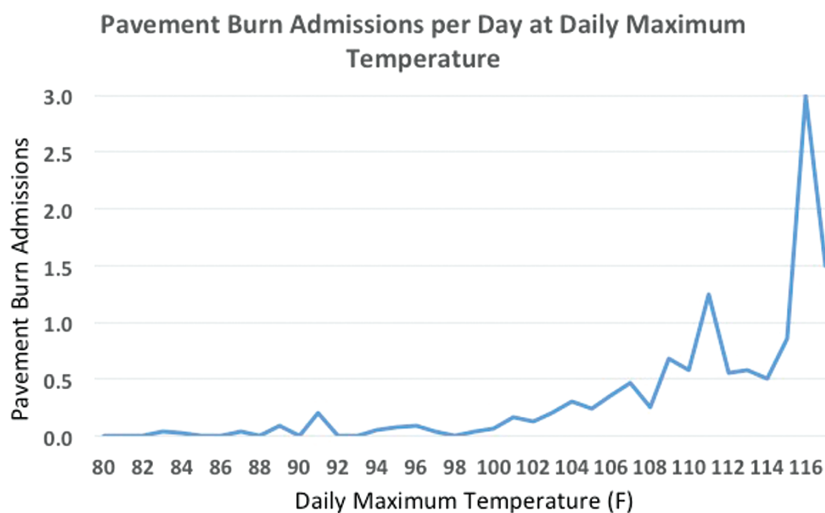


Figure 3. Risk of pavement burn admissions per day at daily maximum ambient temperature.

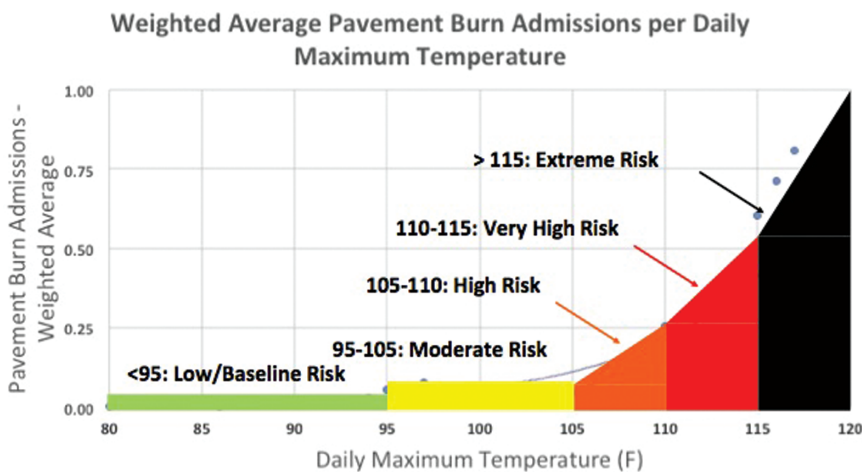


Figure 4. The weighted average of the risk of pavement burn admissions per day at daily maximum ambient temperature.



**Figure 5.** Pavement burn-related injury on the sole of the foot, showing both partial and full-thickness burns.

burn injury to an ambient maximum temperature of 95°F and below, very high risk at ambient maximum temperatures of 110 to 115°F, and extreme risk above 115°F. This information can be used for planning and preparation, since hotter summer climates predictably increases our burn center admissions as temperatures rise. This will help educate our staff on the need for resources and supplies during these months, such as additional pressure off-loading beds and resources for more aggressive operative debridement availability when caring for patients with pavement burns. It can also be used to raise awareness and help maintain a high index of suspicion for deeper burn injuries when notified of a pavement burn injury admission to our center. This information can also be used for burn injury prevention and public health awareness, since the whole community is at risk for hot pavement burns when temperatures are high. Moreover, we plan to use this information to increase awareness and additional training to emergency medical service and police personnel when attending to pavement burn victims in the field.

Some of the limitations in this review include the following: retrospective data from a single center, limited patient information as patient identifiers and individual patient charts were not accessed, weather information from a single source. Data on sunlight intensity was also not available, and this is likely a factor in increasing pavement temperature. Our goals are to expand on this retrospective project and to stratify patients based on age, comparing different age groups and comorbidities. Additionally, we plan to subclassify patients based on degree of burn injury, operative excisions and grafting required per admission and %TBSA, LOS, complications, and other associated injuries sustained at the time of the pavement burn.



**Figure 6.** Pavement burn on the leg with formed eschar. This patient presented about a week after the burn occurred.

The above data illustrates the exponential increase in the rate of burn admissions as maximum ambient temperatures increases. The majority of pavement burns occur at ambient temperatures of 95°F or higher. Patients can be at risk for these injuries in the Southwestern United States or other hot climates with nearly continuous sunlight. These findings highlight the need for continued research, preventive strategies, and resource allocation for pavement burn injuries.

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