ORIGINAL RESEARCH

Search and Rescue in Yosemite National Park: A 10-Year Review

Eric K. Hung, MD; David A. Townes, MD, MPH

From the Department of Psychiatry, University of California San Francisco School of Medicine, San Francisco, CA (Dr Hung); and the Division of Emergency Medicine, University of Washington School of Medicine, Seattle, WA (Dr Townes).

Objective.—To describe the general characteristics and epidemiology of search and rescue (SAR) in Yosemite National Park (YNP) and identify possible areas for intervention directed at reduction in use of these services.

Methods.—Yosemite Search and Rescue (YOSAR) personnel record every search and rescue mission on a Search and Rescue Incident Report. The information contained in these reports was used to perform a retrospective review of all SAR missions within YNP during the 10-year study period between January 1990 and December 1999.

Results.—YOSAR performed 1912 SAR missions, assisting 2327 individuals and recording 2077 injuries and illnesses. Popular trails in and around Yosemite Valley collectively accounted for 25% of all individuals needing SAR services. Lower extremity injuries and dehydration/hypovolemia/hunger were commonly identified reasons to need SAR services. The duration of SAR missions averaged 5 hours, used 12 SAR personnel, and cost \$4400. Helicopter was the primary mode of transport in 28% of SAR incidents. There were 112 fatalities, yielding a SAR case fatality rate of 4.8%. The majority of fatalities occurred while hiking/snowshoeing, with falling the most common mechanism of lethal injury.

Conclusions.—Day-hikers in and around Yosemite Valley use a large portion of SAR services, with lower extremity injuries and dehydration/hypovolemia/hunger the most common reasons. It seems reasonable to direct future intervention to prevention of these commonly identified problems in this particular population of Park visitors.

Key words: National Park Service, search and rescue, wilderness injury and illness, Yosemite National Park

Introduction

Yosemite National Park (YNP) in Northern California encompasses >750 000 acres, an area approximately the size of the State of Rhode Island. Established as a National Park in 1890, this vast wilderness includes pristine alpine meadows, groves of giant sequoia trees, soaring granite cliffs, majestic waterfalls, and turbulent rivers. It is home to a variety of animals, including black bears, coyotes, deer, marmots, and numerous species of birds. Each year, ~4 million people visit YNP to enjoy camping, cross-country and downhill skiing, hiking, rock climbing, and sightseeing.

Corresponding author: David A. Townes, MD, MPH, FACEP, Division of Emergency Medicine, PO Box 356123, University of Washington School of Medicine, Seattle, WA 98195 (e-mail: townesd@u.washington.edu).

Yosemite Search and Rescue (YOSAR) is responsible for the location and evacuation of injured, ill, and lost individuals within YNP; YOSAR receives the highest call volume for technical rescue services within the National Park Service (NPS) and averages ~200 search and rescue (SAR) missions annually.¹ It is 1 of 2 full-time search and rescue services within the NPS and is considered one of the premiere services in the world.

Search and rescue services within YNP are provided 24 hours a day, 365 days a year by the full-time and seasonal staff and volunteers of YOSAR.

Within the NPS, prehospital care providers are divided into 6 skill levels ranging from basic life support (BLS) providers to paramedics. Parkmedics, a level unique to the NPS, are certified emergency medical technicians (EMTs) who are required to have passed the EMT–Intermediate certification exam from the National Registry

of Emergency Medical Technicians (NREMT). In addition, they must have at least 1 year of field experience and have completed a prehospital care internship, emergency department experience, and 120 hours of additional training. The additional training includes advanced patient assessment, use of the esophageal obturator airway and military antishock trousers (MAST), and administration of intravenous therapy including fluids and medications. Standard EMT-Intermediate training and certification does not provide for administration of intravenous medications. Because of prolonged transport times to definitive care within the National Parks, this is regarded as an essential scope of practice for Parkmedics. Some Parkmedics working in YNP have also received advanced cardiac life support (ACLS) certification.^{2,3}

There is a small body of literature dedicated to the description and epidemiology of search and rescue within the National Parks.^{2,3} Because of the large number and diversity of SAR missions in YNP, it serves as an ideal source for this information. The purpose of this study is to describe the general characteristics of SAR in YNP. The results should prove useful for those involved in administration and allocation of emergency medical services (EMSs), training of SAR personnel, injury prevention, and education of the general public.

Methods

Personnel from YOSAR record every SAR mission on a Search and Rescue Incident Report. Completed reports are filed at YOSAR Headquarters in Yosemite Valley. For this study, the information contained in the Search and Rescue Incident Reports was used to perform a retrospective review of all SAR missions within YNP during the 10-year study period between January 1990 and December 1999. In development of the dataset, a unique case number was assigned to each subject. This number contains the year the SAR mission occurred, the sequential number of the incident for that calendar year, and a victim number for that incident.

Search and Rescue Incident Reports contain both descriptive and specific information about the SAR mission, including the location and type of incident, the first responder's patient care report for each victim, and the cost summary report. The location is recorded as 1 of >90 regional districts within YNP. The type of incident, referring to the reason YOSAR was deployed, is categorized as location and evacuation of injured or ill persons, searches for missing persons, or assistance to uninjured or stranded persons.

In addition, the day, month, and year the incident occurred, the time the SAR mission was initiated, the time

Figure 1. Individuals assisted by YOSAR ($n = 2327$).

of arrival of YOSAR at the scene, the time of return, and the number of rescuers involved are recorded.

The report also includes the activity in which the victim was participating and the mechanism of injury, the method of reporting the incident, and the mode(s) of transport of the victim from the location of the incident to definitive care.

Finally, whenever possible, the report contains information from the care facility where the victim was treated, most often the Yosemite Medical Clinic in Yosemite Valley or the Doctor's Hospital and Medical Center in Modesto, CA. For this study, the final diagnosis from the definitive care facility was used when available. When this information was not available, the presumptive diagnosis recorded by YOSAR was used.

The study received approval of the Internal Review Board at our institution, the NPS, and YOSAR. Microsoft Excel software (Redmond, WA) was used in the statistical analysis of the data.

Results

During the study period, YOSAR performed 1912 SAR missions, assisting 2327 individuals and recording 2077 injuries and illnesses. The discrepancy results from SAR missions with multiple individuals with varying numbers of injuries or illnesses.

The median age of the 2327 individuals assisted by YOSAR was 32 ± 16 (SD) years (range, <1–98; mode, 23). Sixty-two percent were men. They were categorized into ill or injured persons, missing persons, and uninjured or stranded persons as shown in Figure 1. Their distribution by year, month, and day of the week are shown in Figures 2–4, respectively. The most common locations where individuals needed SAR services were Yosemite Falls (158), Mist Trail (121), Vernal Falls

Figure 2. Individuals assisted by YOSAR by year ($n = 2193$).

(105), El Capitan (95), and Half Dome (92), collectively accounting for 25% of all individuals requiring SAR services. These trails are in and around Yosemite Valley, an area that represents $\sim 1\%$ of the total area of YNP.

The most common injuries and illnesses are listed in Table 1. Fractures were the single most common reason to need SAR services (416), with fractures of the ankle being the most common (150). Sprains and strains were the next most common reason to need SAR services (290), with sprains and strains of the ankle the most common (162). Sprains and strains of the knee (93) and fractures of the lower leg (92) were also common. Dehydration/hypovolemia/hunger was the most common nontraumatic reason to need SAR services (172). The most common activities individuals were participating in when the incident occurred are listed in Table 2.

Notification of YNP authorities of an incident needing SAR services occurred by radio or standard telephone (61%), verbal communication (34%), or cellular telephone (5%). Of note, although there was only 1 incident reported by cellular telephone in 1990, there were 50 in 1999.

The total duration of SAR missions, defined as the time from notification of YOSAR to arrival at definitive care, averaged 5 hours and 0 minutes. The response time, defined as the time from notification of YOSAR to arrival on scene, averaged 3 hours and 6 minutes, and the transport time, defined as the time from arrival on scene to arrival at definitive care, averaged 1 hour and 54 minutes. The average number of SAR personnel per incident was 12 (range, 1–216), with an estimated average cost per rescue of \$4400.

Helicopter was the primary mode of transport of the individual in 28% of all SAR missions. Other primary modes of transport included ambulance (21%), litter carry (15%), SAR member assist (15%), horse or mule (8%), self (5%), snowmobile (4%), and swift water rescue apparatus or boat (4%).

Table 1. Most common injuries and illnesses needing SAR services ($n = 2077$)

Type of Injury or Illness	N	Percent
Fracture	416	20.0
Sprain/strain	290	14.0
Unspecified	253	12.2
Dehydration/hypovolemia/hunger	172	8.3
Contusion	157	7.6
Laceration	143	6.9
Cold injury/hypothermia/frostbite	95	4.6
Abrasion	91	4.4
Nausea/vomiting	63	3.0
Dislocation	50	2.4

There were 112 fatalities within YNP during the study period, resulting in a SAR case fatality rate of 4.8%. The majority of fatalities were men (83%), with an average age of 37 years. The most common activities that the victim was participating in when the fatality occurred were hiking/snowshoeing (28%), rock climbing and scrambling (23%), and driving a motor vehicle (15%). The most common causes of death were falling (41%), being struck by or striking something including motor vehicle accidents (21%), drowning (17%), and cardiac arrest (10%).

Discussion

During the 10-year study period between January 1990 and December 1999, YOSAR performed 1912 SAR missions, treated 2077 injuries and illnesses, and assisted 2327 individuals, 74% of whom had sustained an injury or illness.

As one might predict, the majority of SAR missions occurred between May and September, with the peak being in July (Figure 3). Similarly, there was an increase on weekend days, with Saturday accounting for the greatest number of SAR missions (Figure 4). These re-

Table 2. Most common activities victims were participating in at time of incident ($n = 2327$)*

Activity	N	Percent
Hiking/snowshoeing	1208	52.0
Rock climbing/scrambling	442	19.0
Driving	139	6.0
Skiing	130	5.6
Leisure/working	101	4.3

*Activity data were unavailable for 148 individuals.

Figure 3. Individuals assisted by YOSAR by month ($n = 2193$).

sults are not surprising and most likely reflect increased visitation during those times. Specific census data were not available, so the exact relationship between visitor census and use of SAR services could not be determined. The results do, however, confirm that additional SAR personnel should be assigned during those times, a practice already in place by YOSAR.

The most common locations for SAR missions to occur were popular trails in or near Yosemite Valley, including Yosemite Falls Trail, Mist Trail, and Vernal Falls Trail. The most common activity at the time of injury was hiking/snowshoeing (Table 1). Again, without specific census data, it is unclear whether this simply reflects the number of individuals hiking on these trails or whether there is something inherent to the individuals or trails that result in more injuries. These results may, in part, reflect the use of these trails by day-hikers, who are generally less experienced, less prepared, and may lack the proper footwear compared with hikers in the backcountry. Further study is necessary to test this hypothesis.

The most common injuries were those of the lower extremity, including fractures, sprains and strains of the ankle, lower leg, and knee, accounting for 24% (497) of all injuries and illnesses. Several other studies have yielded similar results. A study of Sequoia and Kings Canyon National Parks identified lower extremity trauma as the most common injury.² In another study of 8 National Parks, >70% of nonfatal injuries were musculoskeletal or soft-tissue injuries, with the majority involving the ankle and knee.⁴ Sprains and soft tissue injuries accounted for 80% of all injuries recorded in a study of students and instructors of the National Outdoor Leadership School, with ankle injuries the single most common.⁵ In a study of hikers on the Appalachian Trail, blisters, skin chafing, acute joint pain, and diarrhea were the most common reasons for hikers to quit.⁶ These results further support the hypothesis that injuries might

Figure 4. Individuals assisted by YOSAR by day ($n = 2181$).

be reduced through education and use of proper footwear.

During the study period, the majority of incidents were reported by radio or regular telephone, with reporting by cellular telephones accounting for only 5%. The use of cellular telephones, however, increased during this period from a single report by cellular telephone in 1990 to >50 in 1999, a trend that has undoubtedly continued. It has been suggested in the SAR community that this has given rise to "cell phone vigilantes," individuals who take risks assuming rescue is just a cellular telephone call away. Additional studies are needed to determine the impact of increasing use and reliance on cellular telephones on use of SAR services since 1999.

Averaging 5 hours in duration, 12 rescuers, and a cost of \$4400, SAR missions in YNP use a large amount of resources in terms of time, money, and manpower and endanger the lives of YOSAR personnel. These averages may not completely reflect the true use, because some SAR missions consumed a disproportionate amount of resources. At least 1 search for a missing person during the study period took several days and >200 SAR personnel.

The majority of transport of victims was done by helicopter. Whereas helicopters have certainly revolutionized SAR and have become the vehicle of choice for many SAR services, they have important limitations, including weather, daylight, visibility, cost of operation, and danger to the personnel.

The most common causes of death were falling, being struck by or striking something including motor vehicle accidents, drowning, and cardiac arrest. In a study of mortality in 8 National Parks (not including YNP), the 3 most common causes of death were cardiac arrest,

drowning, and falling.⁴ In a similar study of wilderness deaths in children in western Washington State, drowning and closed head injuries were the most common causes of death.⁷

During the study period, 112 of the 2237 individuals assisted by YOSAR were fatalities, yielding an overall case fatality rate of 4.8%. The case fatality rate of individuals needing YOSAR assistance while climbing or scrambling was 1.1% and 3.7% for individuals participating in other activities, respectively. These results suggest that, from a SAR standpoint, "safe" activities such as hiking have a higher case fatality rate than rock climbing and scrambling. In another study, however, questionnaires were given to rock climbers presenting to the Yosemite Medical Clinic or rescued by YOSAR during 3.5 climbing seasons, resulting in a case fatality rate of 6%.⁸ It would certainly be useful to calculate a case fatality rate for all participants in each activity, but unfortunately, specific activity census data were not available for either study.

A study of wilderness mortalities over a 13-year period estimated that alcohol was "a very probable" or "a probable" causative factor in 40% of traumatic deaths and 8.3% of medical deaths. In that study, the most common causes of traumatic death were falls, drowning, and motor vehicle crashes, with heat exposure and cardiac disease being the most common nontraumatic causes of death.⁹ It would be interesting to know how alcohol, substance abuse, and suicide contributed to deaths in YNP, but this information was not available.

Conclusion

OPPORTUNITIES FOR INTERVENTION

In our study, lower extremity injuries were the most common traumatic and dehydration/hypovolemia/hunger were the most common nontraumatic reasons to need SAR services, collectively accounting for 24% of all SAR missions. The data suggest that a large portion of SAR services is used by day-hikers in and around Yosemite Valley. It seems reasonable to focus intervention on prevention of commonly identified injury and illness, including lower extremity injuries and dehydration/hypovolemia/hunger through education of day-hikers in YNP. Educational information could be provided to visitors on entrance to the park and in the Visitor Center through direct, informal interaction with Park staff, educational displays and videos, and formal educational presentations. Special attention should be directed toward individuals who inquire about day-hikes near or within Yosemite Valley. Additional staff could be stationed at popular trailheads to provide further education,

especially during summer weekends. In Grand Canyon National Park, staff members are stationed at popular trailheads to ensure hikers have enough food and water before proceeding down from the rim of the canyon.

Educational materials directed at prevention of dehydration/hypovolemia/hunger should include guidelines for fluid and calorie requirements while hiking. In our study, information about type of footwear was not available; however, education about the prevention of lower extremity injuries should focus on proper footwear and hiking technique. Water safety, especially for children, is another potential focus for education intended to reduce the incidence of drowning in the Park.

LIMITATIONS

There are several limitations to this study. First, the Search and Rescue Incident Reports were completed by different individuals with variable medical training and experience and thus may be inconsistent. Second, reports often contained signs and symptoms rather than a final diagnosis. Finally, without specific census information, it is uncertain whether the use of SAR resources observed simply reflects census or whether there is something inherent about certain activities, individuals, locations, or time periods that contribute to use of SAR resources.

Reduction in preventable use of SAR resources should result in reduced morbidity and mortality among park visitors, reduced risk to SAR personnel, and significant monetary savings. Intervention should focus on prevention of commonly identified injury and illness, including lower extremity injuries and dehydration/hypovolemia/hunger through education of day-hikers in YNP. Further study is necessary to investigate the potential impact of educational programs in reduction of use of SAR within YNP.

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