

SCIENTIFIC INVESTIGATIONS

A survey of positive airway pressure therapy preparedness and outcomes following Hurricane Irma in patients with obstructive sleep apnea

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Study Objectives: Clinical benefit from positive pressure therapy is dependent on treatment adherence. Extreme weather events, such as floods, hurricanes, and tornadoes, can contribute to nonadherence by electricity loss and mandatory evacuation. We aimed to evaluate the concerns and behaviors of regular positive airway pressure users surrounding the extreme weather event Hurricane Irma.

Methods: A questionnaire on positive pressure concerns surrounding Hurricane Irma was completed by 117 patients with pre-hurricane objectively confirmed treatment adherence as defined by Medicare. Responses were tabulated to identify concerns and behavior in preparation for and after Hurricane Irma. Cloud-based monitoring, available on 50 (43%) cases, was used to determine the effect of self-reported electricity loss on treatment adherence before and after the storm. Quantitative use data pre- and post-Hurricane Irma was compared by *t* test with *P* < .05 considered statistically significant.

Results: Post-hurricane 78 (67%) patients were unable to use treatment with mean duration of 4.3 days. Of these, snoring, choking, and sleepiness were reported in 64%, 19%, and 42%, respectively. Loss of electricity was identified as the cause of missed treatment in 71 patients. In those with cloud monitoring, mean 14-day pre- and post-hurricane use differed by 8 minutes (*P* = .056). Cloud-monitored cases with loss of electricity had a decline in mean use of 33 minutes for the first 7 days post-hurricane. There was a trend towards increased use post-hurricane in those that retained electricity. Many patients expressed dissatisfaction with the availability of preparedness guidelines.

Conclusions: Although common, loss of electricity was not the sole disruptor of positive pressure use after extreme weather events. Regular users of positive airway pressure experience both disruption in patterns of use and concerns regarding preparedness for extreme weather events.

Keywords: obstructive sleep apnea, positive airway pressure, extreme weather events, hurricane, nonadherence

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Positive airway therapy is the most effective treatment for obstructive sleep apnea, but adequate compliance is imperative. During extreme weather events, such as a hurricane, treatment adherence may be affected.

Study Impact: Behavioral changes regarding concerns and preparedness of regular users of positive airway pressure, as well as compliance to therapy information, have not been reviewed. The aim of this study is to determine what actions can be taken to minimize treatment interruptions, as well as to provide updated preparation information.

INTRODUCTION

Obstructive sleep apnea (OSA) is a chronic condition characterized by recurrent upper airway collapse during sleep associated with transient hypoxemia and disruption of sleep architecture.¹ In addition to adverse effects on sleep and quality of life, untreated OSA is increasingly recognized for its contribution to cardiovascular disease and mortality.² Positive airway pressure (PAP) remains the first-line and most efficacious therapy for moderate to severe OSA³; however, the effectiveness of this treatment is limited by inconsistent use.⁴ Nonadherence is defined as mean of ≤ 4 hours of use per night,⁵ and in US samples, estimates of long-term PAP adherence are disappointingly low, varying between 46% and 89%.⁶ PAP use is a chronic, complex health behavior requiring continuous maintenance for an individual, his or her

social support network, and involvement of regular health care utilization.^{6,7}

The most important and least well-studied variables affecting PAP adherence remain psychosocial variables.⁶ For example, individuals who engage in shift work and variable sleeping schedules have worse PAP therapy adherence.⁴ Even among experienced adherent PAP users, acute life events may disrupt the routine of consistent PAP. For example, divorce, loss of employment, and death of a family member have each been associated with detrimental adherence to medical treatment.^{8,9} Another common barrier to regular PAP use is travel. Even for the experienced user, traveling with PAP requires preparation to have uninterrupted use. Changing sleeping environments as rarely as once per month can be associated with worse PAP adherence.¹⁰ Preemptive discussion by sleep providers concerning

Table 1—Positive airway pressure (PAP) questionnaire.

1. In the days before Hurricane Irma, were you worried that you might have to sleep without PAP?
a. If yes, why?
b. If no, why not?
2. Did you make any special arrangements to ensure that you could use PAP (eg, generator, battery, etc)?
a. If yes, what arrangements?
b. If no, why not?
3. Did you research what to do with PAP during or after Hurricane Irma (eg, search the Internet, call your doctor, or other)?
a. If yes, what arrangements?
b. If no, why not?
4. Were you able to use PAP as usual and without interruption during and after Hurricane Irma?
a. Yes, if yes, skip questions 5, 6, 7.
b. If no,
5. How many nights did you sleep without PAP?
6. Without PAP, did you experience
a. Snoring
b. Awakenings with choking while asleep
c. Restless sleep
d. Daytime sleepiness or fatigue
e. Headache
f. Increase in nocturia
7. Were you not able to use PAP as usual because of
a. Loss of electricity?
b. Misplaced equipment (left elsewhere)?
c. Hurricane-related equipment failure?
d. Other

acute life events may help mitigate the negative impact of these events on treatment use.

The year 2017 set records for extreme weather events (EWEs) such as hurricanes, floods, forest fires, and landslides. An article comparing a decade of EWEs starting in 2010 demonstrated that even though throughout the years there were floods, fires, and tornadoes, 2017 was the most destructive.¹¹ In 2017, there were 17 storms, 10 hurricanes, and 6 major hurricanes, causing destructive winds and flooding rains. EWEs may disrupt daily routines via necessary evacuation, loss of electricity, direct property damage, heightened stress, and diversion of attention and resources. The acute and sudden evacuation process associated with EWEs may up-end treatment routines for individuals with OSA. Although preparedness information is available for users of other life-sustaining medical equipment (eg, supplemental oxygen, mechanical ventilation), PAP therapy is not typically represented in this category.¹²

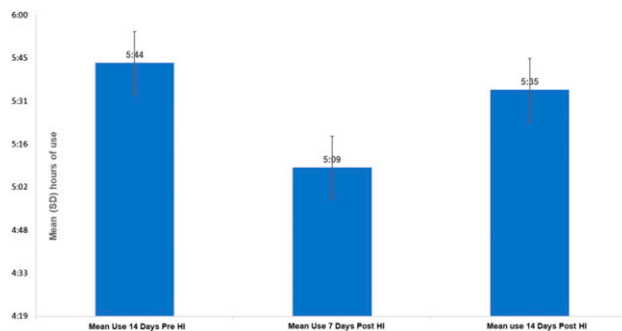
Hurricane Irma (HI) made landfall in the Florida Keys as a Saffir-Simpson scale category 4 storm on Saturday, September 9, 2017, and hit mainland Florida as a category 3 storm packing winds exceeding 110 miles/hour at 1 PM Eastern time on Sunday, September 10. Irma proceeded to cut a path through Florida, arriving in Georgia as a tropical depression on September 11.¹³ By Monday, September 11, 2017, 1.86 million homes and businesses in Miami-Dade, Broward, and Palm

Beach counties lost electricity from Florida Power and Light (FPL).¹⁴ Most power outages occurred in Miami-Dade county, where 71% of Florida Power and Light's 1.1 million customers were without power. The National Hurricane Center estimated a total of 50 billion dollars in wind and water damage from HI, at the time making it the fifth costliest storm to affect the United States.¹⁵

To our knowledge, there are few data describing the effects of EWEs on PAP adherence. Our center's location in hurricane-prone South Florida provides a unique opportunity to assess individuals' concerns regarding preparedness for EWEs and observe the impact of EWEs on patterns of PAP treatment use. After HI, we aimed to gain important information about existing educational gaps concerning preparedness for future EWEs and to learn how to better serve individuals with OSA for future EWEs.

METHODS

To isolate the effect of the extreme weather event, HI, we decided to study a population who had previously demonstrated adherence based on the Centers for Medicare and Medicaid Services criteria.¹⁶ To accomplish this, we analyzed cloud-based data to determine objective trends in PAP adherence

Figure 1—Effect of loss of electricity on PAP use after Hurricane Irma.

Mean PAP use for 14 days before and the first 7 and 14 days after Hurricane Irma (HI) in 27 patients who self-reported HI-related loss of electricity. Paired *t* test *P* values between 14 days before and 7 and 14 days after HI are .29 and .71, respectively

and used a survey to gauge more clearly the concerns and preparedness planning of our patient population.

Patient selection occurred from either of two sources: an Internet-based monitoring system—AirView (version 4.6.0-37.0.0, ResMed 2017, San Diego, California) database—or via clinic follow-up of patients. Patients identified from AirView and clinic follow-up totaled 609 and 42 patients, respectively, thus including 651 patients. The AirView cohort had documented compliance on the 90 days preceding HI, whereas the clinic follow-up patients were selected between September 18 and October 24, 2017; compliance within 30 to 90 days before HI was acceptable. Patients then selected were asked to fill out a questionnaire that queried different elements of interest, such as preparation, use, symptoms if unable to use PAP because of electrical outage, and suggestions for future improvements (Table 1).

Of the 651 patients identified, 117 completed the PAP survey. The PAP survey was administered either in person by practitioners during clinic encounters or via telephone interview. Some patients who completed the questionnaire in the clinic used the AirView platform.

Data on PAP use 14 days before HI (August 28 to September 10), 7 days after HI (September 11 to September 17), and 14 days after HI (September 11 to September 24) were available from cases with AirView-based monitoring. The data were further portioned by those with and without self-reported loss of electricity post HI.

We used the two-tailed paired variates of the student *t* test for statistical analysis of objective PAP use for the entire group before and after HI. The two-tailed unpaired variates of the student *t* test were used to compare PAP use before and after HI of the cohort without loss of power with those who did lose power. Unless otherwise stated in the text, PAP use data are expressed as mean hour:minutes per day ± (standard deviation).

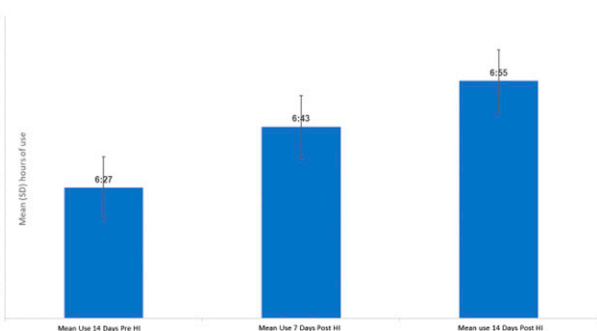
RESULTS

A total of 651 patients with documented PAP compliance for up to 90 days before HI were identified to participate in the study.

Table 2—AirView-derived positive airway pressure use 14 days before and after Hurricane Irma.

	Pre-HI	Post-HI	<i>P</i> value*
All cases (n = 50)	06:04 (01:17)	06:12 (02:10)	.58
Retained electricity (n = 23)	06:27 (01:28)	06:55 (01:34)	.05
Lost electricity (n = 27)	05:44 (02:10)	05:35 (02:26)	.71

Data depicted is mean ± (SD) of 14 days pre and post Hurricane Irma. **P* value derived by two tailed paired *t* test. HI = Hurricane Irma.

Figure 2—PAP use after Hurricane Irma without loss of electricity.

Mean PAP use for 14 days before and the first 7 and 14 days after Hurricane Irma (HI) in 23 cases without HI-related loss of electricity. Paired *t* test *P* values between 14 days before and 7 and 14 days after HI are .30 and .05, respectively.

Of these, 117 patients (18%) were contacted by phone or in clinic and completed the PAP survey. A total of 56 patients had significant concerns about the use of PAP during the hurricane independent of the severity of their sleep apnea; 12 (21%) did some research in an attempt to prepare for the storm, and 22 (39%) patients admitted taking special preparations for the hurricane, including evacuation and the use of generators.

After HI, 78 patients were unable to use their PAP for a range of between 1 day and 14 days, with a mean of 4.3 days without use. Residual symptoms such as snoring were reported in 50 (64%) patients, choking in 15 (19%), restless sleep in 34 (43%), and excessive daytime sleepiness in 33 (42%) patients. Other potential causes of excessive daytime sleepiness include unstable sleeping arrangement and an increased use of anxiolytics and sedatives that could affect central neurotransmitters implicated in the modulation of sleep.¹⁷

Missed PAP occurred predominantly from power outages and misplaced equipment during evacuation. Lack of sufficient power outlets in shelters and failure of adaptations used for religious observance were less common causes of missed PAP. Lack of fresh PAP supplies was not identified as a cause of missed PAP therapy.

A total of 71 patients self-reported loss of electricity during HI. AirView PAP use data were available for 50 (43%) of the 117 cases, 27 with and 23 without HI-related loss of electricity.

Table 3—Advice for positive airway pressure device users preparing for an extreme weather event.

Plan early, have your PAP and accessories handy, and have your carrying case nearby.
If no distilled water is available for your humidifier, it is acceptable to use bottled water or potable tap water.
Avoiding consuming excess alcohol (eg, at “hurricane parties”) as this can worsen sleep apnea and the quality of your sleep.
Maintain a copy of your PAP prescription in case of loss or damage.
If unable to use your PAP for some time, try to sleep on your side.
If planning to evacuate, familiarize yourself with the availability of electricity.
Know how your sleep apnea affects your well-being, and plan accordingly; if you feel really bad when not wearing your PAP, consider investing in a battery pack.
Extend battery life by disabling the humidifier.

PAP = positive airway pressure.

Table 4—Positive airway pressure battery availability by manufacturer and model.

Manufacturer/Brand		Integrated Battery	Portable Battery by Manufacturer
DeVilbiss	IntelliPAP 2 AutoAdjust CPAP	No	No
	IntelliPAP AutoAdjust		
	IntelliPAP Standard Plus		
	IntelliPAP Standard		
Fisher & Paykel	Icon Auto	No	No
	Icon Premo		
	Icon Novo		
	SleepStyle 254 Auto		
Phillips/Respironics	DreamStation Auto CPAP	No	Yes
	DreamStation CPAP Pro		
	DreamStation CPAP		
	DreamStation Go Auto CPAP	Optional	Yes
ResMed	AirSense 10 AutoSet and AutoSet for Her	No	Yes
	AirSense 10 Elite		
	AirSense 10 CPAP	Optional	Yes
	AirMini Travel Auto CPAP		
Somnatic Transcend	Travel CPAP	Optional	Yes
	XZEX Travel CPAP		
	Auto Travel CPAP		
Human Design Medical	Medical Z1 Auto Travel CPAP	Optional	Yes
Apex Medical	XT Fit Travel CPAP	No	No
	iCH Auto CPAP		
3B Medical	RESmart Auto CPAP	No	No
	Luna Auto CPAP		
	Luna CPAP		

CPAP = continuous positive airway pressure.

PAP use data for 14 days pre- and post-HI can be found in [Figure 1](#) and [Table 2](#). As a group, mean 14-day pre- and post-HI daily PAP use differed by 8 minutes ($P = .56$). The longitudinal pattern of PAP use in the those that did and did not lose electricity can be seen in [Figure 1](#) and [Figure 2](#), respectively.

Most participants identified the use of a rechargeable battery as one of the most important resources that could help in preparation for EWEs. Other participants identified emails from providers, directions to approved websites, and in-person or

printed educational materials during clinic visits as desirable for future EWEs.

DISCUSSION

Our findings suggest that regular PAP users experience both disruption in patterns of use and concerns regarding preparedness. In contrast to more traditional causes of PAP nonadherence such

as medical comorbidities, mask discomfort, aerophagia, claustrophobia, and upper airway desiccation,^{18,19} most users cited power loss as the reason for nights spent without PAP. Indeed, loss of electricity post-HI was associated with a temporary decrease in PAP use, whereas PAP use increased after HI in those without loss of electricity (Figure 1 and Figure 2). Admittedly, the changes in PAP use failed to reach statistical significance, an observation possibly related to sample size and variability in the time without electricity. Increased opportunity for sleep or recovery from previous insufficient sleep might explain the observed increase in PAP use observed in cases without loss of electricity. The method of data collection and variability of personal circumstances (loss of employment, damage to property, health issues) do not allow insight into this finding.

Many patients expressed dissatisfaction with the availability of guidance. It is apparent that a commonly utilized source of information is the Internet and that many users consult the websites of the manufacturers of PAP equipment. Although there is a variety of information available in easily accessible language, the issue of extreme weather or hurricane preparedness is not explicitly addressed. For example, a search of keywords, such as *hurricane*, *storm*, and *power out*, did not produce any results in the website search engine provided by the PAP manufacturer ResMed, whereas the website of PAP manufacturer Phillips/Respironics (Murrysville, Pennsylvania) queried with the same keywords produced results for *power out*, including options to purchase battery packs and travel tips for PAP users. A search of the terms *sleep apnea*, *respiratory failure*, *continuous positive airway pressure (CPAP)*, *PAP*, and *mechanical ventilation* on the Florida Power & Light website yielded either no response or identified documents related to its heating, ventilation, and air-conditioning program and building ventilation. A query of The American Sleep Apnea Association (Washington, DC)²⁰ and its affiliated AWAKE (Alert, Well, and Keeping Energetic) group returned information from its sleep health forum regarding Hurricane Harvey CPAP relief. Additionally, the American Lung Association (Chicago, Illinois) website was mute on issues pertaining to PAP sleep apnea treatment and hurricanes.

Most survey respondents reported interest in alternative PAP power sources. Although a detailed query of scientific literature did reveal a helpful review of such power sources,²¹ the information is not readily available to patients. Table 3 offers EWE preparedness advice, and Table 4 lists available power options by PAP manufacturer and model.

Another potential source of information is government websites, which typically publish preparedness tips during storm watch and warning conditions. The most recent version of the Miami-Dade County division of the Florida Health website encourages the preparation of “vulnerable populations” to include coordination with the Miami-Dade Office of Emergency Management, American Red Cross, home health care agencies, hospital, oxygen and durable medical equipment providers, and others. Some of the patients we surveyed had reached out to local shelters and durable medical equipment providers and reportedly were not quoted any specific policies to address PAP use.

Importantly, not all interruption of adherent PAP use in the patients surveyed was attributable to power loss. This finding suggests that behavioral factors influence adherence before and after EWEs. Some patients were frank in admitting they felt overwhelmed by the planning process and did not prioritize PAP use. This issue highlights the psychosocial factors of complex behaviors as well as the importance of self-efficacy and activation. Others surveyed did not perceive symptomatic benefit from their PAP and, hence, were not concerned that they might lose nights on PAP. A unique reason for interrupted use was power-related failure of a PAP-start timer, preventing PAP use for an observer of the Jewish Sabbath.

The limitations of this study include a small sample size, low questionnaire response rate, as well as the recall bias inherent in the retrospective survey method of data collection. Our data highlight the negative effect of EWEs on PAP use as well as user desire for additional information. It is unknown whether the observed uncertainties and experienced interruptions in PAP use have any lasting effects on PAP adherence or subsequent quality of life; however, it is reasonable to assume that improvements in preparedness education would only benefit our patient population.

ABBREVIATIONS

CPAP, continuous positive airway pressure
 EWEs, extreme weather events
 HI, Hurricane Irma
 OSA, obstructive sleep apnea
 PAP, positive airway pressure

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DISCLOSURE STATEMENT

The authors have no conflicts of interest to disclose. All authors met the four criteria for authorship established by the International Committee of Medical Journal Editors: Aleksandra Kwasnik, Pamela Barletta, Alexandre Abreu, Catalina Castillo, Yoel Brito, and Alejandro Chediak are responsible for the conception, design, and drafting the work; revising the work; and reviewing the manuscript. All authors provided final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring including the accuracy and/or integrity of the work. The authors have no financial interests in any companies or other entities that have an interest in the information in the contribution (e.g., grants, advisory boards, employment, consultancies, contracts, honoraria, royalties, expert testimony, partnerships, or stock ownership in medically related fields).