Effects of CPAP Treatment Interruption Due to Disasters: Patients with Sleep-disordered Breathing in the Great East Japan Earthquake and Tsunami Area

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Abbreviations:
AHI: apnea hypopnea index
EDS: excessive daytime sleepiness
nCPAP: nasal continuous positive airway pressure
OSAS: obstructive sleep apnea syndrome
SDB: sleep-disordered breathing

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Abstract

Introduction: The 2011 Great East Japan Earthquake caused major disruptions in the provision of health care, including that for patients with sleep-disordered breathing (SDB) using a nasal continuous positive airway pressure (nCPAP) device. This study investigated the ability of SDB patients to continue using the nCPAP device in the weeks immediately following the earthquake, whether inability to use the nCPAP device led to symptom relapse, and measures that should be taken to prevent disruptions in nCPAP therapy during future disasters.

Hypothesis: If nCPAP devices cannot be used during disasters, SDB patients' health will be affected negatively.

Methods: Within 14 days of the disaster, 1,047 SDB patients completed a questionnaire that collected data regarding ability to use, duration of inability to use, and reasons for inability to use the nCPAP device; symptom relapse while unable to use the nCPAP device; ability to use the nCPAP device use at evacuation sites; and recommendations for improvement of the nCPAP device.

Results: Of the 1,047 patients, 966 (92.3%) had been unable to use the nCPAP device in the days immediately following the earthquake. The most common reason for inability to use the nCPAP device was power failure, followed by anxiety about sleeping at night due to fear of aftershocks, involvement in disaster-relief activities, loss of the nasal CPAP device, and fear of being unable to wake up in case of an emergency. Among the 966 patients, 242 (25.1%) had experienced relapse of symptoms, the most common of which was excessive daytime sleepiness (EDS), followed by insomnia, headache, irritability, and chest pain.

Conclusion: Developing strategies for the continuation of nCPAP therapy during disasters is important for providing healthy sleeping environments for SDB patients in emergency situations.

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Introduction

On March 11, 2011, at 14:46:18 (2:46:18 PM) Japanese Standard Time, the 2011 Great East Japan Earthquake, also referred to as the Tohoku Region Pacific Coast Earthquake, struck the northern coastal areas of the main island of Japan. The strongest ever recorded in Japanese modern history, the earthquake triggered a massive tsunami that inflicted catastrophic damage on the Pacific coastal areas of the Tohoku regions and massive disruption in infrastructure in inland areas, disrupting the power supply to approximately 8 million households. It also inflicted massive disruption to the lives of those residing in these areas, particularly those suffering from serious health conditions. Obstructive sleep apnea syndrome (OSAS) is a common disease with a morbidity rate of 2%-4%.[1] Although one large-scale epidemiological study reported racial differences in the

prevalence of OSAS, specifically a high prevalence among individuals of African and Asian descent compared to Caucasian, it examined OSAS prevalence in only Europe and the United States. Subsequent studies observed no differences in the prevalence of OSAS in Europeans or Americans compared with the Japanese.[2,3] Obstructive sleep apnea syndrome is associated with a high rate of comorbidity, particularly comorbidity with mood and anxiety disorders, which are associated with sleep deprivation. Indeed, long-term disturbance in the quality of sleep is a well-known, predisposing factor for exacerbation of psychological distress and mental illness.[4] Obstructive sleep apnea syndrome presents with daytime sleepiness, a cognitive dysfunction related to hypersomnolence due to frequent nocturnal awakenings. One study found that when frequent one-minute sleep disruptions are imposed in a multiple sleep-latency test, increase in sleepiness, as indicated by a mean reduction in the rate of sleep-onset time, results in changes comparable to those occurring with fragmented nighttime sleep.[5] Moreover, OSAS reportedly impairs mental and physiological functioning. The deterioration that was observed during functional testing evaluating specific behaviors or activities and attention was associated with the nocturnal apnea hypopnea index (AHI) and the frequency of nocturnal awakenings. Fortunately, application of nasal continuous positive airway pressure (nCPAP) therapy has been found to improve these test results.[6-8]

In accordance with epidemiological studies showing that sleep-disordered breathing (SDB) is a risk factor for hypertension,[9] OSAS is considered a primary cause of secondary hypertension. In a study of public employees in Wisconsin (United States) that measured AHI with overnight polysomnography, and blood pressure in the same subjects over four years, an AHI of 15 events per hour or higher was shown to be an independent risk factor for the development of hypertension, compared with an AHI of 1.5 events per hour or lower.[10] Fortunately, the use of nCPAP therapy has been shown to relieve hypertension and improve left ventricular diastolic performance in OSAS patients.[11] Headache is another complication of OSAS, and one study reported that OSAS patients complained of morning headaches more frequently than healthy people.[12]

To date, no study, to the authors' knowledge, has investigated the frequency of relapse of OSAS symptoms after discontinuation of nCPAP therapy due to a disaster such as an earthquake. To fill this research gap, this study investigated the ability to continue nCPAP therapy and whether inability to use the nCPAP devices had led to a relapse of OSAS symptoms after the onset of the Great East Japan Earthquake and its consequences, as well as identified countermeasures that should be taken to prevent disruptions in nCPAP therapy during future disasters.

Methods

In this observational study, the initial study sample consisted of 1,053 OSAS patients residing in northern Japan and receiving nCPAP therapy at the Division of Behavioral Sleep Medicine of Iwate Medical University Hospital, the Department of Pulmonary Medicine of Hachinohe Red Cross Hospital, or the Morioka Silent Sleep Clinic. Of these 1,053 patients, 1,047 completed the questionnaire, yielding a response rate of 99.4% (Figure 1). Six subjects whose responses to the questionnaire were incomplete were excluded from this study. During outpatient visits in July 2011, the investigators interviewed patients about the situation within 14 days of the earthquake using an original questionnaire

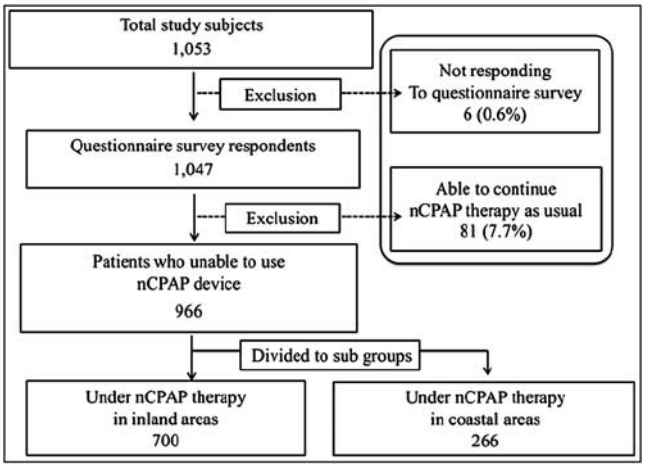

Figure 1. Study Subjects
Abbreviations: nCPAP, nasal continuous positive airway pressure

(Appendix) that investigated the situation. The questionnaire consisted of six items that collected data regarding (1) the ability to continue using the nCPAP device as a means of continuing nCPAP therapy; (2) the duration of inability to use the nCPAP device; (3) reasons for the inability to use the nCPAP device; (4) symptom relapse while unable to use the nCPAP device; (5) the ability to continue or resume nCPAP device use at evacuation site; and (6) recommendations for improvement of the nCPAP device to prevent the development of subjective health problems at evacuation sites. The existence of health problems was defined as the recurrence of symptoms that had existed prior to the initiation of nCPAP treatment, such as daytime somnolence, hypersomnolence, frequent nocturnal awakening, and morning headache. This study was approved by the Ethics Committee of the Iwate Medical University Hospital.

Data for statistical analysis were collected from the questionnaire survey and were analyzed by simple tabulation. Stat View 5.0 (SAS Institute Inc., Cary, North Carolina, USA) was used to perform all analysis.

Results

Ability to Use the nCPAP Device

Of the 1,047 patients examined, 81 (7.7%) were able to continue nCPAP therapy after the earthquake, while 966 (92.3%) were unable to do so. Among the 286 patients residing in the coastal area that had been devastated by the tsunami, 266 (93.0%) had been unable to continue nCPAP therapy, whereas 700 (92.0%) of 761 patients residing in the inland areas, which had not been directly affected by the tsunami, had been unable to continue nCPAP therapy.

Duration of Inability to Use the nCPAP Device

Among the patients residing in the coastal areas, 98 (36.8%) had been unable to use the nCPAP device for five to seven days followed by 95 patients (35.7%) for one to two days, 47 (17.5%) for three to four days, and 26 (9.8%) for seven days or more. Among the patients residing in the inland areas, 343 (49.0%) had been unable to use the nCPAP device for one to two days, followed by 257 patients (36.7%) for five to seven days, 51 (7.3%) for three to four days, and 49 (7.0%) for seven days or more (Figure 2).

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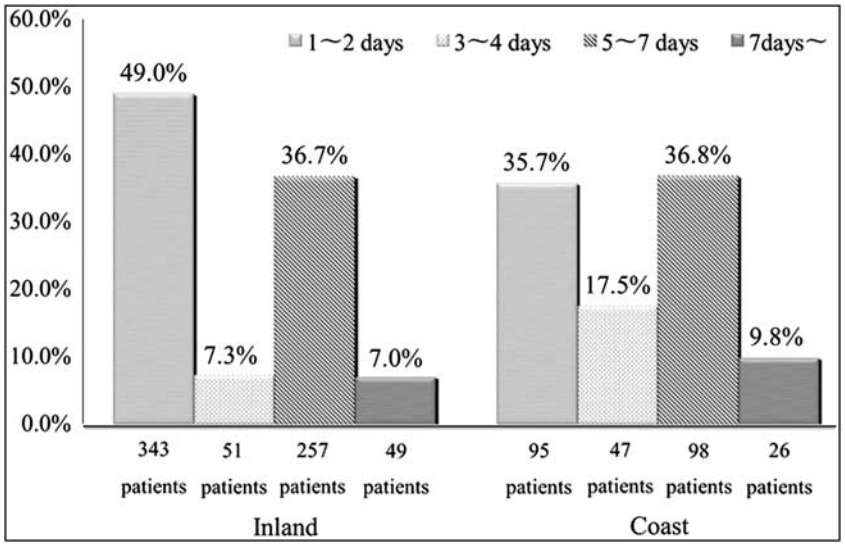

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Figure 2. Number of Days when Subjects were Unable to Use the nCPAP Device
Abbreviations: nCPAP, nasal continuous positive airway pressure

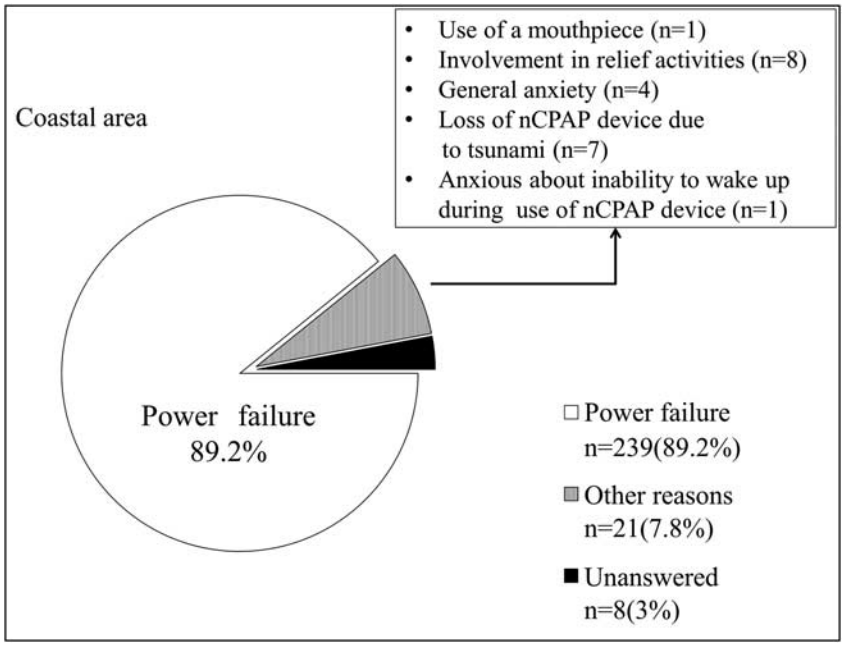

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Figure 3A. Reasons for Inability to Use the nCPAP Device in Coastal Area
Abbreviations: nCPAP, nasal continuous positive airway pressure

Among the 44 patients (31 in the coastal areas and 13 in the inland areas) who had remained at the evacuation site and had been unable to use the nCPAP device, 33 (75.0%), of whom 24 (77.4%) resided in the coastal areas and 9 (69.2%) in the inland areas. Regarding the duration of inability to use the nCPAP device among these 44 patients, 16 (36.4%), the largest number, had been unable to use the device for seven days or more.

Reasons for Inability to Use the nCPAP Device

Among the 966 patients who had been unable to use the nCPAP device, the most common reason for such inability was power failure, which was reported by a total of 879 (91.0%) in the coastal and inland areas (Figures 3A, 3B). Other reasons included anxiety about sleeping at night because of the possibility of aftershocks; involvement in disaster-relief activities; loss of the nCPAP device; and fear of being unable to wake up in case of an emergency, such as an aftershock, while using the nCPAP device.

Symptom Relapse While Unable to Use the nCPAP Device

Among the 966 patients who were unable to use the nCPAP, 242 (25.1%) had experienced relapse of OSAS symptoms due to this inability. The most-commonly reported symptom was excessive daytime sleepiness (EDS), which were experienced by 165 patients (17.1%), followed by insomnia, headache, irritability, and chest pain.

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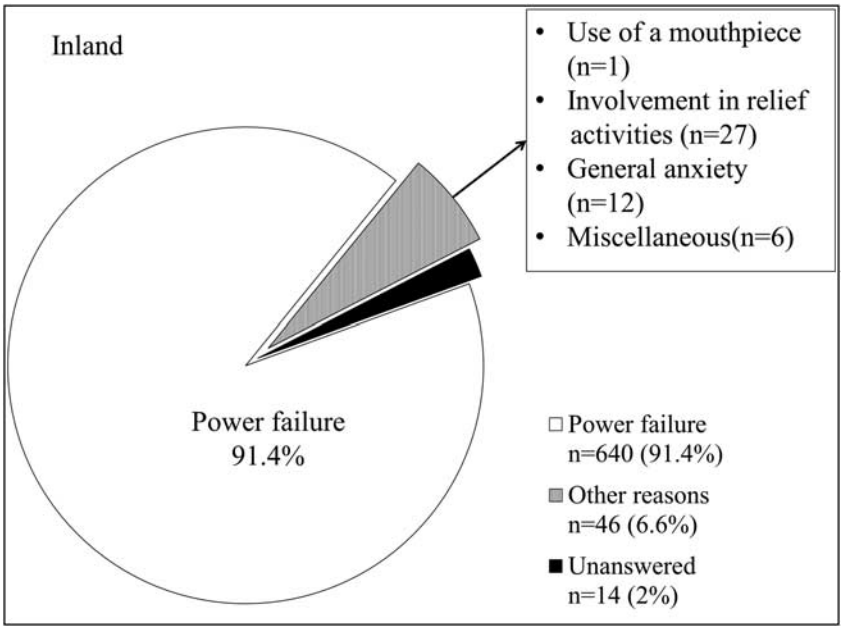

Figure 3B. Reasons for Inability to Use the nCPAP Device in Inland Area
Abbreviations: nCPAP, nasal continuous positive airway pressure

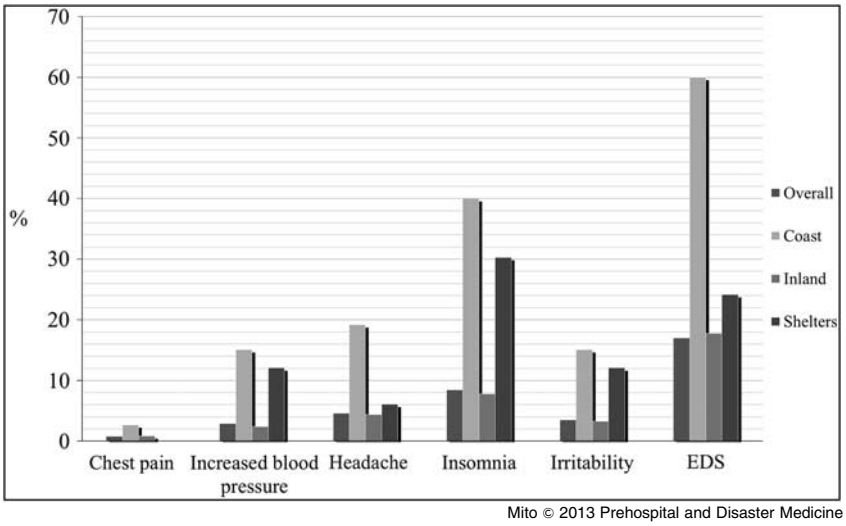

Figure 4. Frequency of Sleep Apnea Syndrome-associated Symptoms
Abbreviations: EDS, excessive daytime sleepiness

Relapse of OSAS symptoms was common among patients who remained in the coastal areas or had temporarily stayed at emergency shelters. Of those who reported relapses, 60.0% of those remaining in coastal areas and 24.2% of those who had temporarily stayed in shelters reported having experienced EDS. Forty percent of those remaining in coastal areas and 30.3% of those staying in shelters reported having experience insomnia (Figure 4).

Use of the nCPAP Device at Evacuation Sites and Shelters

Of the 44 patients who had stayed at evacuation sites or emergency shelters, 21 (47.7%) had experienced health problems. Of the 11 who had been able to use the nCPAP device while remaining at evacuation sites, one patient, who resided in a coastal area, reported having experienced a health problem. Of the 33 patients who had been unable to use the device while staying at emergency shelters, 20 (60.6%) had experienced health problems. Among the patients remaining in the inland areas who had been able to use the nCPAP device, none reported having experienced health problems. In contrast, among the patients who had been unable to use the nCPAP device, 15 (62.5%) of 24 patients in the coastal areas and five (55.0%) of nine in the inland areas reported having experienced health problems (Figure 5).

Recommendations for Improvement of the nCPAP Device to Avoid Emergence of Subjective Health Problems at Evacuation Sites

Among the improvements to the nCPAP device recommended by 44 patients to increase its ease of use after an earthquake or other major disaster, the most common were enablement of silent

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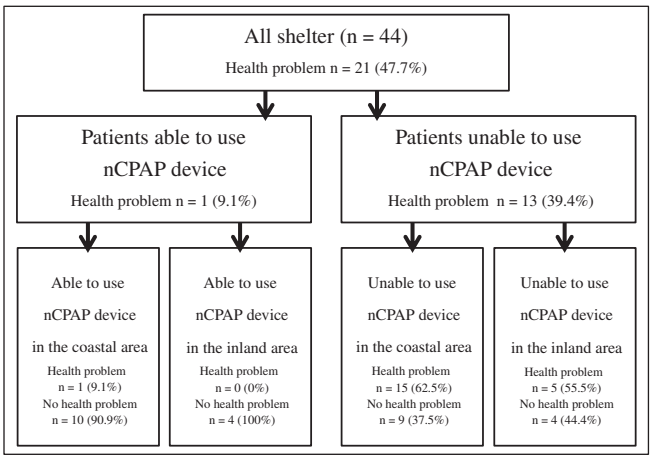

Figure 5. Proportions of Patients with and without Ill Health After the Disaster
Abbreviations: nCPAP, nasal continuous positive airway pressure

operation, which was recommended by 30 (68.2%) patients; decreasing the size, which was recommended by 26 (59.1%); enabling battery operation, which was recommended by 31(70.5%); and decreasing its weight, which was recommended by 38 (86.4%).

Discussion

The Great East Japan Earthquake left 15,867 dead, 6,109 injured, and 2,903 missing.[13] In the Pacific coastal areas, many victims lost their homes, requiring them to live temporarily at communal evacuation sites such as gymnasiums and schools unequipped to provide long-term residence. Consequently, relatively few victims required so-called disaster medical care, which mainly consisted of treatment for injury. Medical assistance organizations dispatched to affected areas immediately after the disaster, such as Disaster Medical Assistance Teams, transported victims requiring emergency medical care to rearguard medical institutions. Thus, the most difficult challenge in the affected areas was not providing disaster medical care but rather preventing sudden interruption of ordinary medical care for common chronic diseases. Furthermore, inland areas, although protected from tsunami damage, as well as areas surrounding the Pacific coast, experienced electrical power failures lasting from several days to several weeks,[14] greatly disturbing the routines of people residing in these areas. Disaster victims also experienced secondary effects on their health due to interruption of medical services.

Effects of the Disaster on nCPAP Device Users

The results of this study revealed that SDB patients who had been using an nCPAP device as a form of nCPAP therapy prior to the earthquakes experienced difficulty in using the device in the weeks following the disaster. Except for a small number who had lost their devices, this difficulty can be attributed mainly to interruptions in the power supply.

Effects of Interruption of nCPAP Therapy on the Health of nCPAP Device Users

Sleep-disordered breathing is a pathological condition frequently complicated by comorbid conditions such as obesity,[15] hypertension,[16,17] and glucose metabolism disorder;[18,19] daytime symptoms such as sleepiness and headache;[20,21] and sleep-related symptoms and conditions such as snoring and sleep disorder. Administration of nCPAP therapy is known to alleviate these comorbid pathological conditions and improve prognosis, especially for OSAS patients.[22-28] Because nCPAP therapy is a palliative treatment, its interruption exacerbates complications. A previous assessment using the Medical Outcome Study 36-Item Short-Form Health Survey (SF-36) reported poor scores, especially for vitality, for patients with mild to moderate SDB, as well as on many subscales of health-related quality of life for those with severe SDB.[29] Another study found that snoring associated with OSAS impairs the quality of life of patients as well as their bed partners.[30] To the authors' knowledge, this was the first study to evaluate the treatment of health problems in OSAS patients forced to interrupt nCPAP therapy due to a large-scale disaster, to determine the impact of this interruption on the health of patients and their families, and to identify the means of avoiding these problems during future disasters. Of the 1,047 nCPAP users examined in this study, 528 (50.4%) were forced to interrupt nCPAP therapy for three days or more. Among the 966 patients who were unable to use their nCPAP devices and had experienced symptoms relapse, the most common was EDS (165 patients). In accordance with this finding, a study that compared patients who had been able to continue nCPAP therapy to those whose therapy had been interrupted due to ordinary life situations observed relapse of EDS within two to three days of interruption.[31] Another study of interruption of nCPAP therapy in OSAS patients observed relapse of EDS to an extent that attention to difficult tasks was impaired after interruption for two nights.[32]

Occurrence of EDS due to forced interruption of nCPAP therapy is likely to adversely affect the quality of life at evacuation sites and during rescue work. When nCPAP device users are forced to sleep without using the device, they are likely to inflict adverse effects on evacuees sleeping within their vicinity, particularly by their snoring, leading them to become hyper vigilant to their surroundings, which further decreases the quality of their sleep.

Chest pain, a symptom often reported in the questionnaire, might have been a psychosomatic symptom rather than a symptom attributable to a physical illness such as ischemic heart disease. However, investigation of the origin of this symptom was not possible, as identification of pathological conditions was difficult. Several studies that examined the effect of interruption of nCPAP therapy for a certain period on the cardiovascular system reported that interruption of therapy for one week or longer rapidly affects endothelial function and increases urine catecholamine levels, blood pressure, and heart rate.[33,34] As 75 (7.2%) of the 1,047 nCPAP users in the present study reported that they were unable to use the nCPAP device for seven days or more, it is likely that they had cardiovascular disease. Moreover, because it was likely that they had not been aware of the OSAS symptoms assessed in the survey when using the nCPAP device before the disaster, an association between symptoms relapse and device use likely exists. Indeed, a previous study reported an association between arrhythmia and sudden death in patients with OSAS.[35] These findings suggest that the impact of inability to use the nCPAP device for an extended period should be further investigated.

The Great East Japan Earthquake struck at 2:46 PM Japanese Standard Time, a time when many nCPAP device users had been

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at work without their nCPAP devices, some of which were swept away with the user's homes. The results of this study revealed that although most users did not lose their devices, many subsequently experienced difficulty using them, primarily because of inability to activate the nCPAP device due to disruption of the power supply. For the largest proportion of nCPAP users, seven days or more passed before power was restored, a finding in accordance with reports that power restoration occurred only after eight days in more than 90% of the disaster-stricken areas.[36]

Of the 44 nCPAP device users who had been forced to seek shelter at communal evacuation sites, 33 had been unable to continue or resume nCPAP therapy due to the power conditions at the sites. Other commonly-reported challenges to device use had been the allotment of an extremely narrow sleeping space for each evacuee; difficulty in obtaining electricity for personal use; and difficulty in using alternative coping strategies, such as sleeping in the lateral position. Furthermore, because of their awareness of their loud snoring during sleep, it is likely that the nCPAP device users were hyper vigilant of the effect of their sleep symptoms on fellow evacuees, disrupting their own sleep and that fellow evacuees. It should be emphasized that more than half of the nCPAP users who had been unable to use their nCPAP devices while staying at evacuation sites had experienced health problems.

To be eligible for reimbursement for nCPAP therapy from the Japanese health insurance symptom, OSAS patients must have an AHI of ≥ 20 and experience moderate to severe OSAS. For such OSAS patients, nCPAP therapy is a minimum requirement to maintain health, along with the ability to eat and excrete. The generally recommended treatment strategy for these patients is undergoing nCPAP therapy four hours or longer every night for 70% of a continuous period. Although limited information is available regarding the duration of treatment interruption before relapse of clinical symptoms and deterioration of prognosis, data collected thus far indicate that simply falling asleep is often difficult for patients with severe disease at the time of treatment interruption. Thus, interruption of nCPAP therapy may be serious for patients with more severe pathological conditions.

The results of this study indicated that a main factor in the exacerbation of the health problems experienced by nCPAP device users had been the lack of infrastructure, particularly of the continuous power supply, necessary to continue treatment. The emergence of this factor has been difficult to predict even during normal (non-disaster) times, as reflected by previous reports that approximately 20% (range, 5%-50%) of nCPAP device users do not use their nCPAP devices at a sufficient frequency or sufficiently continuously, even with an unlimited supply of power.[37-39] Nevertheless, the usefulness of the device may be understood only when its continuous use becomes impossible. Although the actual number was not determined, many nCPAP device users reported that they experienced the beneficial effects of nCPAP therapy after restoration of the electrical power supply. Thus, it may be hypothesized that identifying the physical factors that inhibit continuation of treatment and the means of overcoming these factors before a disaster strikes, if possible, would greatly assist nCPAP device users in coping with their health problems during similar large-scale disasters in the future.

According to the questionnaire results, nCPAP device users desire the development of an nCPAP device that would allow continuation of treatment even during power failure and that would provide greater portability in terms of decreased weight and size. One study found that the most important issue regarding first-response efforts is providing safety during the 48 hours after a disaster strikes, a period during which those affected wait for external rescue and relief.[40]

Power was restored to 90% or more of the households within two days of the Great East Japan Earthquake. Similarly, power was restored to 90% or more of the households within two days after the Great Hanshin-Awaji Earthquake struck in 1995. However, in the Iwate Prefecture, the main survey area chosen for this study, power was restored to approximately 90% of households on March 15, four days after the onset of the disaster.[14] Nevertheless, use of the nCPAP device decreased among its users for more than four days after the disaster occurred, likely due to the limited availability of power at each evacuation site. This finding reflects the fact that at public facilities, especially many temporarily established evacuation sites, it had been difficult to use power for personal needs. Even after restoration of power, many nCPAP device users were unable to use their devices, a fact that likely resulted in their reporting of a desire for development of a device with an internal battery.

Although not part of this study, the SDB patients with various levels of severity included members and technicians of assistance teams involved in rescue and restoration operations in affected areas. For these workers, interruption of nCPAP device use for several days or more during relief efforts likely exacerbated sleep disorder-related complications and increased the risk of accidents during dangerous work. Performance of emergency-preparation measures, such as preparation of emergency oral appliances and provision of pharyngeal surgery, is premised on transferring the patient to a rearguard hospital. Although taking conservative measures, such as using certain postures and bedding, are applicable to a certain extent, their effects are limited, especially in severe cases of SDB. In addition, increase in the agitation and fatigue of disaster victims during evacuation and the circumstances themselves are likely to exacerbate the pathological conditions of SDB. However, in treating subjective complaints associated with sleep disorder, such as being unable to obtain enough sleep and frequently waking during sleep, hypnotics and sedatives are likely to be prescribed without considering their effects on SDB. To ensure the health and safety of nCPAP device users, enabling the aggressive use of the nCPAP device is a more effective strategy than applying conservative therapy with uncertain effects.

Limitations

One limitation of this study was that responses to the questionnaire were subjective. Another limitation was that the patients surveyed resided in only some areas, although the effects of the earthquake extended over a large region. Therefore the findings may not be able to be generalized to the situations in other stricken areas. A third limitation was that the questionnaire consisted mainly of closed question, and thus may not have allowed the subjects to fully express their feelings and opinions. A final limitation was that the responses to the survey might have been interpreted in a subjective manner by the researchers.

Conclusion

Sleep and respiratory disorders due to SDB cannot be resolved using currently available medications, cognitive behavioral therapies or other techniques. In addition to experiencing the psychological stress that arises in an abnormal environment

created by a disaster, the nCPAP device users examined in this study were unable to continue nCPAP therapy due to interruption of the power supply; the provision of extremely narrow sleeping spaces at evacuation sites; and the difficulty in using conservative measures, such as sleeping in the lateral position, at the evacuation sites. The features of the currently provided nCPAP device either did not allow them to overcome these difficulties or made it extremely difficult to do so.

The findings of this study indicate that developing measures that allow for continuation of nCPAP therapy and treatment during disasters is important for providing healthy sleeping environments for SDB patients in emergency situations. The experience of SDB patients during this disaster confirmed that development of a device equipped with features that allow for its continued operation during power failure is needed to avoid the emergence of health problems for these patients during future disasters.

Acknowledgements

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Appendix

Q1. Could you use the nCPAP device as usual after the disaster?

- ☐ Yes→To Q2
- ☐ No→To Q3

Q2. For those who answered "Yes" to Q1, why were you able to use the nCPAP device?

- ☐ Had a power supply
- ☐ Used a home power generator
- ☐ Used a battery (e.g., car battery)
- ☐ Away on business (to another prefecture)
- ☐ Other reason(s) (_____)

Q3. For those who answered "No" to Q1, for how many days were you unable to use the nCPAP device?

- ☐ 1 to 2 days
- ☐ 3 to 4 days
- ☐ 5 to 7 days
- ☐ 1 week or more

Why were you unable to use the nCPAP device?

- ☐ Power outage
- ☐ Lost the nCPAP during the disaster
- ☐ Performing relief activities (Occupation: _____)
- ☐ Fear of power outages
- ☐ Fear of being unable to wake easily when using the device
- ☐ Other reason(s) (_____)

How were you able to sleep without using the nCPAP device?

- ☐ Used a mouthpiece
- ☐ Slept on my side (lateral position)
- ☐ Slept sitting up (seated position)
- ☐ Slept on my stomach
- ☐ Other reason(s) (_____)

Q4. For those directly affected by the disaster, were you able to use the nCPAP device at an evacuation center?

- ☐ Yes
- ☐ No

For those who answered "No" to the above question, what was/were the reason(s)? Check all that apply.

- ☐ Lost the device
- ☐ Had no power source.
- ☐ Did not want to bother others
- ☐ Too embarrassed to use the device
- ☐ Had no privacy
- ☐ Other reason(s) (_____)

Q5. Did you notice any changes in your physical condition while being unable to use the nCPAP device?

- ☐ Yes
- ☐ No

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For those who answered ''Yes'' to the above question, what change(s) did you notice? Check all that apply.

- ☐ Daytime drowsiness
- ☐ Irritability
- ☐ Difficulty in falling asleep
- ☐ Headache
- ☐ Elevated blood pressure
- ☐ Chest pain
- ☐ Other change(s) (_____)

Q6. After the disaster, did your impression of the nCPAP device change?

- ☐ Realized the benefits of device use
- ☐ Felt the same about the device
- ☐ Other (_____)

Q7. What improvement to the nCPAP device would you find beneficial?

- ☐ Enabling quieter operation
- ☐ Decreasing the size
- ☐ Decreasing the weight
- ☐ Enabling battery operation
- ☐ Other (_____)

Q8. Please share any additional thoughts and opinions.

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