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Questionnaire survey on the continuity of home oxygen therapy after a disaster with power outages

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ABSTRACT

Background: After the Great East Japan Earthquake, oxygen-dependent patients in areas experiencing power outages could not continue home oxygen therapy (HOT) without oxygen cylinders. The purpose of this study was to examine use of oxygen cylinders in areas experiencing power outages and the effects of HOT interruption on patients' health.

Methods: Questionnaires were mailed to 1106 oxygen-dependent patients and HOT-prescribing physicians in Akita, near the disaster-stricken area. We investigated patients' actions when unable to use an oxygen concentrator and classified the patients based on oxygen cylinder use. Patients who experienced an interruption of or reduction in oxygen flow rate by their own judgment were assigned to the "interruption" and "reduction" groups, respectively; those who maintained their usual flow rate were assigned to the "continuation" group. Differences were tested using analysis of variance and the χ^2 tests.

Results: In total, 599 patients responded to the questionnaire. Oxygen cylinders were supplied to 574 patients (95.8%) before their oxygen cylinders were depleted. Comparison of the continuation ($n=356$), reduction ($n=64$), and interruption ($n=154$) groups showed significant differences in family structure ($p=0.004$), underlying disease ($p=0.014$), oxygen flow rate ($p<0.001$), situation regarding use ($p<0.001$), knowledge of HOT ($p<0.001$), and anxiety about oxygen supply ($p<0.001$). There were no differences in changes in physical condition.

Conclusions: Most patients could receive oxygen cylinders after the disaster. Some patients discontinued their usual oxygen therapy, but their overall health status was not affected.

1. Introduction

Home oxygen therapy (HOT) is an indispensable therapy for patients with hypoxemia caused by pulmonary or cardiac diseases such as chronic obstructive pulmonary disease, interstitial pneumonia, and chronic heart failure (CHF) [1–5]. Patients can maintain their health and life with continuous HOT [6,7]. In Japan, a national health insurance system is

Abbreviations: HOT, home oxygen therapy; CHF, chronic heart failure

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available to all Japanese citizens, and this system has continually covered the costs of HOT since 1985. Therefore, HOT is widely used for these patients [8]. Typically, patients use an electrical oxygen concentrator at home and use an oxygen cylinder when they are without power or away from home. These cylinders are delivered to almost all patients by oxygen providers.

On March 11, 2011, an earthquake of magnitude 9.0, one of the most powerful and catastrophic ever recorded, and a massive tsunami struck off the east coast of Japan [9]. In a wide area of the northern part of Japan, lifelines were severed and people fled to evacuation centers. There was less damage from this disaster in Akita Prefecture on the west side of the northern part of Japan. Nevertheless, utilities were cut off in all households for 2 days. Because oxygen concentrators were unusable, patients could not continue HOT without oxygen cylinders.

Such catastrophic disasters can occur anywhere in the world, and a scenario in which patients cannot continue HOT because of a large-scale power outage is always possible. Avoiding interruption of treatment in the event of a disaster is essential in maintaining disease stabilization for oxygen-dependent patients [10]. However, little has been reported about the management of patients on HOT during disasters or long-term power outages. In addition, correspondence of risk management efforts during a disaster has not been established. Thus, we investigated how patients continued HOT after a disaster. The purpose of this study was to examine patients' use of oxygen cylinders in areas experiencing power outages resulting from an earthquake. We also evaluated the differences between the characteristics and backgrounds of patients who experienced an interruption of or reduction in their oxygen flow rate by their own judgment and those of patients who continued HOT as usual. We also analyzed health damage caused by the discontinuation of HOT.

2. Material and methods

2.1. Patients

Patients receiving HOT in Akita Prefecture were enrolled in this study, and all patients had used a HOT oxygen concentrator at least until March 11, 2011. These patients had various grades of hypoxemia caused by chronic respiratory or heart failure. The inclusion criterion was that patients or guardians could answer a questionnaire.

2.2. Procedures

We designed the original questionnaire in Japanese to investigate how patients receiving HOT responded after the disaster. The questionnaire was designed according to those used for past disasters in Japan [11].

We obtained written consent from prescribing physicians before the start of the study and extraction of patient data. Questionnaires were sent to patients only if consent was obtained.

First, we evaluated how oxygen was supplied after the disaster. Second, patients who received a supply of oxygen were classified into one of 3 groups based on their oxygen cylinder use. The "continuation" group consisted of patients using the same oxygen flow rate as before the disaster, the "reduction" group consisted of patients who switched to use of an oxygen cylinder but with reduced oxygen flow, and the "interruption" group consisted of patients who did not switch to using an oxygen cylinder. Patients' characteristics, background factors associated with HOT, and damage to health were compared statistically for each group.

Finally, to evaluate whether the oxygen-dependent patients were hospitalized or whether they underwent consultation at a medical institution, we collected information using a questionnaire from HOT-prescribing medical institutions that have hospitalization facilities.

2.3. Questionnaire

Because there was not a proper questionnaire pertaining to the situation of the patients undergoing HOT at the time of the disaster, we created an original questionnaire in Japanese. This 9-item coded questionnaire was used to ask about issues related to HOT at the time of a disaster or power outage. An English translation of the questionnaire is shown in Table 1.

In addition to the previously described information, demographic data including age, gender, underlying disease, and family structure were collected. Information related to HOT was also collected and included the oxygen flow rate, duration of oxygen use, and situation regarding oxygen use. In terms of their knowledge about oxygen, patients were asked whether they knew the capacity of their oxygen cylinder.

Using the questionnaire from HOT-prescribing medical institutions, we recorded the number of patients who were hospitalized or who underwent consultation at a medical institution and the reasons for each case.

2.4. Ethical considerations

This study protected the rights and welfare of the participants in the spirit of the ethical guidelines outlined in the Declaration of Helsinki and followed the ethical principles set forth by the Ministry of Health, Labour and Welfare of Japan. The research plan was deliberated upon and approved by the Ethics Committee of Akita University (No. 923 , June 2012). After providing a complete description of the study, written informed consent was obtained from all participants involved in the present study.

2.5. Statistical analysis

The questionnaire was answered voluntarily, and only a valid response to each question was used for comparison among the 3 groups. Analysis was performed using SPSS (v 18.0; IBM, Armonk, NY). Data are presented as mean and standard deviation (SD) unless otherwise stated. Statistical significance was defined as a P-value <0.05. The χ^2 test was used to examine differences between categorical variables, and an analysis of variance test was used to examine differences in age and oxygen flow rate.

Table 1 – The questionnaire.

Questionnaire for patients treated with home oxygen therapy

Preparing for disasters and power outages

1 Before this earthquake, were you instructed by medical providers about how to deal with oxygen therapy during the disaster?
☐Yes ☐No ☐Others ( )

2 Do you know the capacity of your oxygen cylinder?
☐Yes ☐No

Responses related to home oxygen therapy at the time of disasters and power outages

1 Was your safety confirmed?
☐Yes
→ ☐By family
☐By a medical institution
☐By an oxygen provider
☐No

2 Were oxygen cylinders supplied before the oxygen levels in the current cylinder were depleted?
☐Yes
→ How many oxygen cylinders were supplied?
☐Same as usual
☐Less than usual
→ Were you satisfied with the number of oxygen cylinders delivered?
☐Yes ☐No
☐No
→How long was it until you received new supplies?( ) hours

3 Did you switch to using an oxygen cylinder?
☐Yes
→ ☐Normal flow rate
☐Reduced flow rate
☐No

Changes in physical condition at the time of disasters and power outages

1 Did you experience any anxiety about oxygen supply during a power outage?
☐Yes ☐No

2 Were there any changes in your physical condition?
☐Yes ( ) ☐No

3 Did you visit medical institutions?
☐Yes ( ) ☐No

4 Were you hospitalized?
☐Yes ( ) ☐No

3. Results

3.1. *Patients' characteristics*

Of the 1106 oxygen-dependent patients, 599 patients (54.2%) agreed to participate and responded. The patients' general characteristics are presented in Table 2. The sample consisted of 415 men (69.3%). The mean age was 73.4±18.1 years. The mean oxygen flow rate was 1.61±1.03 L/min at rest. In regard to family structure, 55 patients (9.2%) lived alone, 183 (30.5%) lived in elderly households, and 258 (43.1%) lived with younger family members.

3.2. *Oxygen supply*

Although all patients experienced a power outage, 574 (95.8%) of the 599 patients who replied to our questionnaire were able to maintain their oxygen supply without interruption. Among the valid responses, 309 patients (85.8%) were satisfied with the number of delivered cylinders (Table 3).

Twenty-five patients (4.2%) ran out of oxygen before oxygen cylinders were delivered. However, oxygen cylinders were delivered to all of these patients within 24 h. Data on oxygen flow rate and the period of oxygen interruption for these patients are shown in Fig. 1. Among the valid responses, 7 patients (58%) experienced oxygen interruption for less than 3 h. Although 4 patients (25%) had a high flow rate of oxygen (more than 2.5 L/min), their oxygen was quickly supplied within 1 h.

3.3. *Continuity of HOT during power outages*

Oxygen cylinders were supplied to 574 patients, but 154 (26.8%) did not switch to oxygen cylinders and 64 (11.1%) reduced the oxygen flow rate. Only 356 patients (62.1%) inhaled oxygen as usual.

The 574 patients who received oxygen cylinders were classified into 3 groups, and the characteristics of the patients by group are shown in Table 3. The patients in each group were similar in regard to age, gender, and time using HOT. There were significant differences in their family structure ($p=0.004$), underlying disease ($p=0.014$), oxygen flow rate ($p<0.001$), situation regarding use ($p<0.001$), instructions about HOT ($p<0.001$), knowledge of HOT ($p<0.001$), satisfaction with oxygen supply ($p=0.004$), and anxiety about oxygen supply ($p<0.001$) (Table 3).

Table 2 – Patient characteristics. ($n=599$).

Age (years)	73.4 (18.1)
Gender	
Male	415 (69.3)
Female	184 (30.7)
Family structure	
Alone	55 (9.2)
Elderly households	183 (30.5)
Together with younger family	258 (43.1)
No answer	103 (17.2)
Underlying disease	
Chronic obstructive pulmonary disease	190 (31.7)
Interstitial pneumonia	66 (11.0)
Post-tuberculosis sequelae	42 (7.0)
Cancer	4 (0.7)
Heart disease	74 (12.4)
No answer	223 (37.2)
Oxygen flow rate (L/min)	
Rest	1.61 (1.03)
Effort	1.89 (1.03)
Sleep	1.61 (1.00)
Duration of oxygen use	
Approximately 1 year	97 (16.2)
Approximately 2 years	113 (18.8)
Approximately 3 years	113 (18.8)
More than 3 years	259 (43.4)
No answer	17 (2.8)
Situation regarding oxygen use	
Always	405 (67.6)
Outdoors only	11 (1.8)
Indoors only	117 (19.5)
No answer	66 (11.1)
Safety confirmation[a]	
Family	238 (39.7)
Medical institutions	77 (12.9)
Oxygen provider	266 (44.4)

Age and oxygen flow are expressed as mean (SD), and values in cells represent numbers (%).

[a] For multiple answers, the percentage shown is values divided by 599.

In the interruption group, 79 patients (64.8%) lived together with younger family members, and only 43 (35.2%) lived alone or with an elderly spouse. Conversely, the number of elderly households was higher in the reduction group.

Regarding underlying disease, rates of heart disease were higher in the interruption group than in the other groups. Mean oxygen flow rates were lower in the interruption group than in the other 2 groups, and as many as 72 patients (54.6%) were using oxygen only indoors in the interruption group.

Although there was no difference in the number of supplied oxygen cylinders, satisfaction regarding delivery was lower in the reduction group and higher in the interruption group. The opposite trend was observed for anxiety about the oxygen supply. There were fewer patients in both the interruption and reduction groups who had instructions about what to do during a disaster before the earthquake.

3.4. *Changes in physical condition during power outages*

Only a few patients in each group reported a change in their physical condition (continuation group, 25 [7.2%]; reduction group, 5 [8.7%]; interruption group, 8 [5.3%]). There was no significant difference among the groups ($p=0.622$). The types of changes in physical condition included sleeplessness, headache, and nausea. Only 2 patients reported having any actual respiratory symptoms.

There were no significant differences in patient ratios in each group for consultation with medical institutions or hospitalization ($p=0.635$). The reason for consultation or hospitalization was primarily inhalation of oxygen. No patients reported acute exacerbation of their disease as a reason for hospitalization.

Twenty-one (47.7%) of 44 HOT-prescribing medical institutions responded to the questionnaire. Although there were 49 consultations, most addresses how to handle oxygen therapy during the disaster. Nine patients were hospitalized, 6 continued oxygen therapy, and 3 had some kind of change in physical condition.

4. Discussion

4.1. *Oxygen supply*

There are few reports about continuity of HOT in cases of natural disasters [10,12]. In the case of the Great East Japan Earthquake, power lines were damaged and a wide area of northeastern Japan experienced a power outage. Thus, oxygen cylinders needed to be delivered by oxygen providers immediately. Kobayashi et al. [10] reported how patients continued HOT in areas that were heavily damaged by the tsunami during the disaster. The oxygen providers were unable to deliver sufficient oxygen cylinders for immediate use during emergencies [10].

Fortunately, Akita Prefecture did not experience the severe causalities from the earthquake that were sustained in neighboring areas. Our investigation showed that many oxygen-dependent patients received oxygen cylinders from oxygen providers before the patient's supply of oxygen was depleted. The number of delivered oxygen cylinders was the same as usual, and most patients were satisfied.

Reserve oxygen supplies kept by patients may be a factor that greatly influenced the sufficient surplus of oxygen. Most patients in Japan keep more than 2 cylinders in their home to use for daily outings and emergencies. Theoretically, patients on HOT who inhale oxygen at 1 L/min for 24 h have 2 unused cylinders at home, and the cylinders could be useful for approximately 36 h. Therefore, HOT may not be interrupted even if oxygen supplies are delivered late for patients inhaling at low flow rates.

Another influence could be a change in the systems of oxygen providers. After the Great Hanshin-Awaji Earthquake in 1995, oxygen could only be supplied to 79% of patients in Kobe City [11]. We compared past and present reports submitted by the oxygen providers after the both disasters [13–16] and considered 2 reasons for this.

First, it was reported that the countermeasure manuals of oxygen providers for disasters were not adequately established in 1994. There were some problems with the manuals [13]; however, the main reason why oxygen providers were unable to deliver was that they did not know the whereabouts of patients. Because of disruption to lines of communication, oxygen

Table 3 – Comparison of characteristics and background factors associated with home oxygen therapy and damage to health among 3 groups classified based on oxygen cylinder use.

	No.(%) of patients				P-value
	All ($n=574$)	Continuation ($n=356$)	Reduction ($n=64$)	Interruption ($n=154$)	
Age (years)	73.4 (18.1)	75.2 (14.4)	71.8 (21.2)	70.6 (23.9)	0.858
Gender					
Male	400 (69.7)	255 (71.6)	47 (73.4)	98 (63.6)	0.107
Female	174 (30.3)	101 (28.4)	17 (26.6)	56 (36.4)	
Family structure					
Alone	55 (11.1)	40 (12.7)	3 (5.0)	12 (9.8)	0.004
Elderly households	183 (36.9)	122 (38.8)	30 (50.0)	31 (25.4)	
Together with younger family	258 (52.0)	152 (48.5)	27 (45.0)	79 (64.8)	
Underlying disease					
Chronic obstructive pulmonary disease	181 (51.3)	119 (52.2)	23 (53.5)	39 (47.5)	0.014
Interstitial pneumonia	65 (18.49)	51 (22.3)	6 (13.9)	8 (9.7)	
Post-tuberculosis sequelae	38 (10.8)	24 (10.5)	7 (16.4)	7 (8.5)	
Cancer	4 (1.1)	2 (0.9)	1 (2.3)	1 (1.2)	
Heart disease	65 (18.4)	32 (14.1)	6 (13.9)	27 (33.1)	
Oxygen flow rate (L/min) (rest)	1.61 (1.03)	1.63 (1.06)	1.68 (1.30)	0.91 (0.70)	<0.001
Duration of oxygen use					
Approximately 1 year	90 (16.5)	58 (16.7)	13 (20.3)	19 (12.3)	0.542
Approximately 2 years	106 (19.4)	66 (19.0)	14 (21.8)	26 (16.9)	
Approximately 3 years	102 (18.7)	69 (19.9)	6 (9.3)	27 (17.5)	
More than 3 years	248 (45.4)	153 (44.4)	31 (48.6)	64 (41.3)	
Situation regarding oxygen use					
Always	405 (76.0)	297 (87.8)	51 (80.9)	57 (43.2)	<0.001
Outdoors only	11 (2.1)	7 (2.1)	1 (1.6)	3 (2.2)	
Indoors only	117 (21.9)	34 (10.1)	11 (17.4)	72 (54.6)	
Knowledge of HOT					
Known	352 (66.4)	258 (73.7)	40 (71.4)	54 (43.5)	<0.001
Unknown	178 (33.6)	92 (26.3)	16 (28.6)	70 (56.5)	
Instruction about HOT					
Yes	224 (47.7)	167 (54.9)	20 (37.7)	37 (32.7)	<0.001
No	246 (52.3)	137 (45.1)	33 (62.3)	76 (67.3)	
Number of supplied oxygen cylinders					
Same	347 (91.8)	254 (91.1)	48 (88.9)	45 (100.0)	0.089
Less	31 (8.2)	25 (8.9)	6 (11.1)	0 (0.0)	
Satisfaction for the number of oxygen cylinders					
Satisfaction	309 (85.8)	227 (86.3)	40 (74.1)	42 (97.7)	0.004
Dissatisfaction	51 (14.2)	36 (13.7)	14 (25.9)	1 (2.3)	
Anxiety about oxygen supply					
Yes	356 (65.0)	237 (68.1)	51 (80.9)	68 (49.6)	<0.001
No	192 (35.0)	111 (31.9)	12 (19.1)	69 (50.4)	
Changes in physical condition					
Yes	38 (6.9)	25 (7.2)	5 (8.7)	8 (5.3)	0.622
No	514 (93.1)	320 (92.8)	52 (91.3)	142 (94.7)	
Consultations with medical institutions					
Yes	41 (7.2)	29 (8.1)	5 (8.5)	7 (4.5)	0.326
No	528 (92.8)	327 (91.9)	54 (91.5)	147 (95.5)	
Hospitalization					
Yes	20 (3.5)	14 (3.9)	2 (3.3)	4 (2.6)	0.753
No	549 (96.5)	342 (96.1)	57 (96.7)	150 (97.4)	

Age and oxygen flow are expressed as mean (±SD), and values in cells represent numbers (%). Statistically significant value ($p<0.05$). Nonrespondents are omitted from this total. HOT, home oxygen therapy.

providers could not contact patients and were unable to determine the evacuation destination of patients. Hence, many Japanese oxygen providers developed new counter measure manuals for disasters based on the experiences with past earthquakes [15]. In the case of the Great East Japan Earthquake, according to the new manual, oxygen providers attempted to contact oxygen-dependent patients by telephone. However, because the telephone services experienced major disruptions, oxygen providers visited patients' houses directly in an order based on oxygen flow rate. As a result, the safety of many patients was confirmed by oxygen providers. Our data show that the rate of patient confirmation by oxygen providers

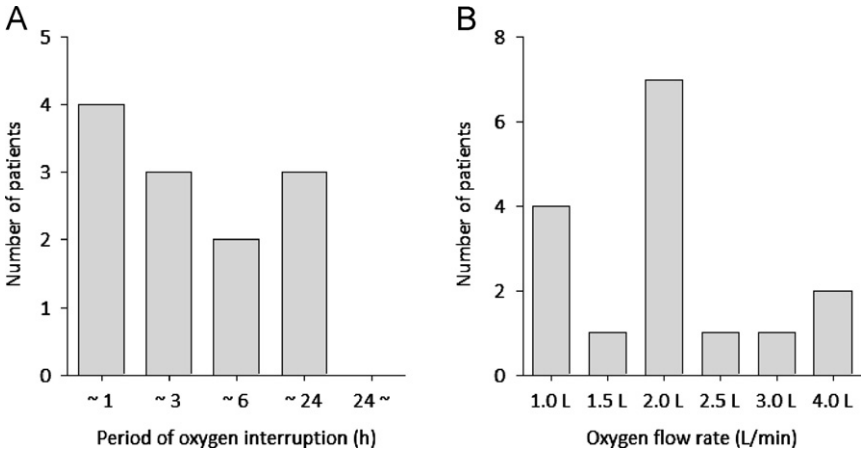

Fig. 1 – Number of patients experiencing oxygen interruption until delivery of new oxygen cylinders in terms of (A) the period of oxygen interruption and (B) the oxygen flow rate.

was greater than that by actual family members. Actually, patients were contacted by oxygen providers more promptly after the Great East Japan Earthquake than after the Hanshin disaster.

Second, some oxygen providers were able to exchange information with administrative departments, hospitals, and visiting nursing stations for the purpose of gathering information on the Great East Japan Earthquake [16]. This type of information exchange might make it possible to provide oxygen more effectively.

Every effort should be made to satisfy customers after a disaster. We worry that services available following a disaster may depend solely on private companies and not on the support of local government, hospitals, or the Respiratory Society.

4.2. *Continuity of HOT*

Although oxygen cylinders could be supplied to almost all patients, interestingly, a considerable number of patients experienced an interruption of or reduction in their oxygen therapy.

According to our results, the characteristics of the interruption group were (1) using oxygen at a low flow rate, (2) not using HOT continuously, (3) living with younger family members, (4) less anxiety, and (5) little knowledge about HOT. Conversely, the characteristics of the reduction group were (1) high anxiety and (2) living alone or with an elderly spouse.

Using a lower oxygen flow rate might mean that patients in the interruption group were not experiencing severe respiratory failure. It is likely that patients with mild oxygen needs might voluntarily interrupt continuous HOT. Of course, a high ratio of patients in the interruption group might inhale oxygen intermittently for the same reasons.

The incidence of heart disease as the underlying disease was greater in the interruption group than in the other 2 groups. Because nocturnal HOT improves exercise capacity, cardiac function, and cardiac sympathetic nerve activity in patients with CHF and central sleep apnea, HOT has been recognized as a valuable nonpharmacological option for the treatment of patients with CHF [3,5,17]. Therefore, in Japan, nocturnal HOT for patients with CHF and central sleep apnea has been covered by the Japanese National Health Insurance System since 2004 and was used before the spread of adaptive servo-ventilation therapy. Patients with CHF treated with HOT, the number of which has been increasing, use HOT only at night, and they may voluntarily interrupt oxygen therapy. Continuous users might be given first priority regarding oxygen supply at the time of a disaster.

Patients with chronic respiratory failure have anxiety about various problems routinely, in particular about physical limitations and dyspnea [18–20]. It was expected that the degree of anxiety might be exacerbated by a disaster, *because these patients need various support even for the everyday life*. However, in the interruption group, only half of the patients expressed anxiety about their oxygen supply. Interestingly, there were more patients who lived with younger family members in the interruption group than that in the other groups.

Family function is clearly better in families of patients undergoing HOT than families of inpatients [21]. These patients must spend most of their time at home, which makes family relationships close [21,22]. In such a relationship, some patients might feel relieved without the continuation of HOT, despite the slight physical handicap.

Conversely, more number of patients in the reduction group lived alone or only with their elderly spouse. Psychological symptoms such as anxiety, depression, and feelings of helplessness in elderly couples are frequently reported in the literature [18,23,24]. Thus, the patients and their elderly spouses experience severe stress, which may become a bigger handicap than having respiratory diseases at the time of a disaster. The results of this study suggest that elderly couples undergoing HOT require strong support and should be a priority over those who live with younger family members.

There were fewer patients in both the interruption and reduction groups than in the continuation group who had instructions from their medical provider before this earthquake about how to handle oxygen therapy after a disaster. A similar tendency was seen in knowledge about the capacity of oxygen cylinders.

Poor education by a medical provider might lead to less knowledge and inappropriate responses in self-care [25,26]. Thus, with thorough guidance, patients may be able to respond more appropriately at the time of disasters and power outages, particularly elderly patients.

4.3. *Changes in physical condition*

Fortunately, although many patients experienced interruptions of or reductions in their oxygen flow, only a few patients reported changes in their physical condition and consulted medical institutions during the disaster.

There were no differences in the proportion of patients among the 3 groups. One of the reasons may be that the power outage lasted for only 2 days. Although the criteria for long-term oxygen therapy are well established, patients with mild oxygen needs could experience improvement of their symptoms with even noncontinuous oxygen therapy [27,28]. In this study, the mean oxygen flow was 1.7 L/min. Based on our investigation, because the severity of patients' oxygen needs was mild, there might be little effect from a short-term interruption in or reduction of oxygen therapy.

4.4. *Study limitations*

We recognize that the present study has some limitations. First, 54% of patients and 47% of medical facilities returned the questionnaires; hence, the number of completed questionnaires might be insufficient for generalizing the results. However, the difference in the number of patients who underwent consultation or who were hospitalized was not significant between the 2 questionnaires. Similarly, the comparison among the 3 groups may not accurately reflect each entire group, although there was no selection bias. Second, our questionnaire was intended to investigate the actual situation following a disaster. However, we did not use an objective index about physical or mental findings, and thus we may not have evaluated the patients' mental and physical changes exactly. A questionnaire that includes anxiety scores should be used to evaluate patients' mental changes more precisely. Third, this investigation was performed in neighboring Akita Prefecture and not in the center of the disaster-stricken area. Therefore, our survey may not reflect the situation in a directly stricken area. Because the duration of the power outage was not long, we cannot estimate from our data what may occur during a longer outage.

4.5. *Conclusions*

Even following a large-scale disaster, almost all oxygen-dependent patients could receive oxygen cylinders. Patients with severe oxygen dependence and patients in elderly households should be given first priority regarding oxygen supply at the time of a disaster. Although some patients in this study experienced interruptions or reductions in their oxygen supply, the overall health of patients was not affected.

Conflict of interest

The authors have no potential conflict of interest.

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