

Original Article

Analysis of patients with decompression illness transported via physician-staffed emergency helicopters

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ABSTRACT

Context: There have been few reports investigating the effects of air transportation on patients with decompression illness (DCI). **Aims:** To investigate the influence of air transportation on patients with DCI transported via physician-staffed emergency helicopters (HEMS: Emergency medical system of physician-staffed emergency helicopters). **Settings and Design:** A retrospective medical chart review in a single hospital. **Materials and Methods:** A medical chart review was retrospectively performed in all patients with DCI transported via HEMS between July 2009 and June 2013. The exclusion criteria included cardiopulmonary arrest on surfacing. Statistical analysis used: The paired Student's *t*-test. **Results:** A total of 28 patients were treated as subjects. Male and middle-aged subjects were predominant. The number of patients who suddenly surfaced was 15/28. All patients underwent oxygen therapy during flight, and all but one patient received the administration of lactate Ringer fluid. The subjective symptoms of eight of 28 subjects improved after the flight. The range of all flights under 300 m above sea level. There were no significant differences between the values obtained before and after the flight for Glasgow coma scale, blood pressure, and heart rate. Concerning the SpO₂, statistically significant improvements were noted after the flight (96.2 ± 0.9% versus 97.3 ± 0.7%). There were no relationships between an improvement in subjective symptoms and the SpO₂. **Conclusion:** Improvements in the subjective symptoms and/or SpO₂ of patients with DCI may be observed when the patient is transported via HEMS under flights less than 300 m in height with the administration of oxygen and fluids.

Key Words: Air transportation, decompression illness, physician-staffed emergency helicopters

INTRODUCTION

In March 2004, the emergency medical system of physician-staffed emergency helicopters was initiated in eastern Shizuoka prefecture, located near Tokyo. This system primarily transports patients in severe condition from Izu Peninsula to the emergency and critical care center. The helicopter parks at our hospital,

which has an emergency and critical care center but no large recompression medical equipment for treating decompression illness (DCI). DCI is caused by the presence of intravascular and/or extravascular bubbles that form as a result of a reduction in environmental pressure (decompression).^[1] The term covers both arterial gas embolism, in which alveolar or venous gas emboli (formed via cardiac shunts in the pulmonary vessels) are introduced into the arterial circulation, and decompression sickness, which is caused by *in situ* bubble formation from dissolved inert gas.^[1] When a patient on Izu Peninsula develops DCI, the physician-staffed emergency helicopter picks up the patient at a rendezvous area, where the patient is transported by ambulance to a medical facility with large recompression equipment [Figure 1]. When a patient with DCI is transported by air, the signs and symptoms of the patient may deteriorate due to exposure to further decompressive circumstances.^[2,3] However, there have been few reports investigating the effects of air transportation on patients with DCI.^[4,5] Accordingly, we retrospectively investigated the influence of air transportation on

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patients with DCI transported via physician-staffed emergency helicopters.

MATERIALS AND METHODS

The retrospective study protocol was approved by the review board of Juntendo Shizuoka Hospital, and the examinations were conducted according to the standards of good clinical practice and the Helsinki Declaration.

A medical chart review was retrospectively performed in all patients with DCI transported via physician-staffed emergency helicopters between July 2009 and June 2013. The exclusion criteria included cardiopulmonary arrest on surfacing.^[6] The diagnosis of DCI was made based on clinical findings, such as accurate history taking and physical examinations in individuals who developed symptoms after diving, referring to the SAN Diego Diving and Hyperbaric Organizations (SANDHOG) criteria, including presenting symptoms of poor coordination, muscle weakness, numbness, or vertigo after diving.^[1,7] DCI has classically been categorized into type I and type II disease.^[8] The type I form involves the joints (bends) and corresponding ligaments, lymphatics, and skin, whereas the type II form involves the central nervous system (CNS), lungs (choking), and cardiovascular system.

Patient age, sex, depth of diving, duration of diving, whether the patient suddenly surfaced, the type of DCI, oxygen therapy, administration of fluids, range of the flight level, changes in subjective symptoms, changes in vital signs (Glasgow coma scale, blood pressure, heart rate, percutaneous oxygen saturation: SpO₂) before and after flight, interval between request and arrival at the medical facility, and the survival rate were analyzed.

The statistical analyses were performed using the paired Student's *t*-test. A *P*-value of <0.05 was considered to indicate a statistically

significant difference. All data are presented as the mean ± standard error.

RESULTS

During the investigation period, 34 patients with DCI were transported via physician-staffed emergency helicopters. Of these patients, six experienced cardiopulmonary arrest on surfacing after diving complicated by drowning. Excluding these six cases, a total of 28 patients were treated as subjects. Figure 2 presents a flowchart of the subject stratification and selection process.

Table 1: Background characteristics of the subjects

Variable	Number or average
Number	28
Sex	
Male	20
Female	8
Age (years)	45.2±1.9 (range 21-61)
Depth of diving (m)	26.2±2.5 (range 9-60)
Duration of diving (minute)	25.7±2.9 (range 6-50)
Suddenly surfacing	
Yes	15
No	13
Type of decompression sickness	
CNS	18
Choke	4
Choke and bends	2
Choke and CNS	4
Oxygen therapy (l/min)	10.3±0.5 (range 3-15)
Administration of lactate fluid	27
Range of flight above sea level (m)	150-300
Change of subjective symptoms	
Before and after the flight	
Deterioration	0
No change	20
Improvement	8 (Choke 1, Choke and CNS 2, CNS 5)
Request: Arrival at medical facility	
minute	62.7±4.3 (range 26-121)
Survival rate (%)	100

CNS = CENTRAL NERVOUS SYSTEM



Figure 1: Map of Izu Peninsula. A photo taken from a helicopter indicating Juntendo Shizuoka Hospital where the helicopter parks. The two crosses indicate medical facilities with large medical equipment for recompression.

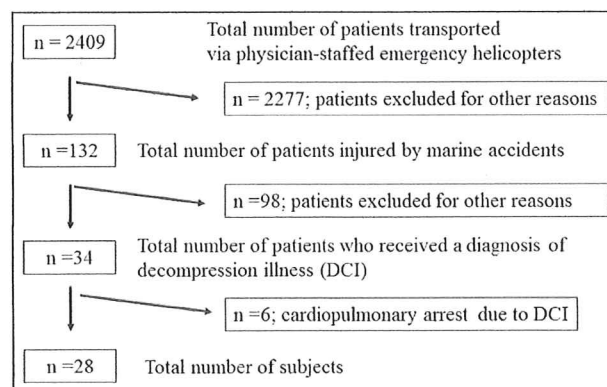


Figure 2: Flowchart of the stratification and selection of the subjects. Ultimately, 28 patients were included as subjects.

Oode, *et al.*: Decompression illness transported via HEMS

The background characteristics of the subjects are shown in Table 1. Male and middle-aged subjects were predominant. The number of patients who suddenly surfaced was 15/28 (53.5%), including five cases of type II DCI, four cases of running out of oxygen, four cases of panic, one case of nitrogen narcosis, and one case of the use of the buddy system to care for a diver with type II DCI. The symptoms of two patients with DCI began after showering, and the remaining patients developed symptoms while diving or upon surfacing. All patients underwent oxygen therapy during flight. A total of 25 of the 28 patients were transported while wearing a reservoir mask that delivered 10-15 l/min oxygen (10 l/min: 21 subjects and 15 l/min: Four subjects). Three patients were transported under 3-6 l/min of oxygen delivered via a mask without a reservoir (three, five, and six l/min for one subject each, respectively). The oxygen therapy was maintained from the time of contact with the emergency medical technicians to arrival at the medical facility. The duration of oxygen therapy from contact with the emergency medical technicians to arrival at the medical facility was similar in all patients, as shown in Table 1. All subjects were transported in the supine position in the helicopter, and all but one patient received the administration of lactate Ringer fluid. The symptoms of the patient who did not receive lactate Ringer solution subsided when the physician assessed the patient at the rendezvous area. The subjective symptoms of eight of 28 subjects (28.5%) improved after the flight. The range of all flights was under 300 m above sea level.

The changes in vital signs are shown in Table 2. There were no significant differences between the values obtained before and after the flight for blood pressure and heart rate. Concerning the SpO₂, statistically significant improvements were noted after the flight (96.2 ± 0.9% versus 97.3 ± 0.7%). There were no relationships between an improvement in subjective symptoms and the SpO₂. The average Glasgow coma scale score decreased after the flight. Four patients underwent tracheal intubation under the use of sedatives and muscle relaxants to secure the airway or support the respiratory function. After excluding these four cases, the same tendency was observed.

Unfortunately, all but two subjects were transported to other medical facilities; thus, we were unable to obtain follow-up data for the subjects, including the length of intensive care unit (ICU) treatment, in-hospital duration, or final outcome.

Table 2: Changes in vital signs before and after the flight

	Before	After	P value
Glasgow coma scale	14.2±0.2	13.0±0.7	P=0.06
	14.6±0.1	14.6±0.1	n.s.*
Blood pressure (mmHg)	120.0±3.7	120.9±3.4	n.s.
Heart rate (per minute)	86.8±3.5	86.7±3.4	n.s.
SpO ₂ (%)	96.2±0.9	97.3±0.7	P<0.01
Oxygen therapy (l/min)	10.3±0.5	10.3±0.5	n.s.

MEAN ± STANDARD ERROR, N.S.: NOT SIGNIFICANT, *: THE RESULTS OF THE STATISTICAL ANALYSIS AFTER EXCLUDING FOUR PATIENTS TREATED WITH TRACHEAL INTUBATION UNDER SEDATIVE USE

DISCUSSION

This is the first report to demonstrate an improvement in subjective symptoms and/or SpO₂ in patients with DCI after diving transported via helicopter under flights less than 300 m in height with the administration of oxygen and fluid.

The management of DCI involves hyperbaric oxygen treatment, which is best initiated as soon as possible because the recovery is improved with early treatment.^[9] However, the distance to the hyperbaric chamber can be a barrier to providing expedient treatment.^[2] Often, the most rapid transport is by air, although air transport may exacerbate the symptoms of DCI due to further decreases in atmospheric pressure following the expansion of trapped nitrogen gas and increased amounts of gas leaking from the solution.^[2,3] Accordingly, it is important to pressurize the aircraft or fly at a low altitude in order to minimize the decrease in pressure.^[2,3] Concerning the height of the permissible altitude of flight for patients with DCI, there are only two reports investigating such clinical data. Reddick reported six cases of DCI occurring after artificial depressurization training in patients transported by helicopter. According to that report, three patients with the DCI symptoms worsened when the helicopter altitude exceeded 213 m (700 feet)–304 m (1,000 feet) above the ground level.^[5] In the remaining three patients, no changes in symptoms were observed when the helicopter remained below 152 m (500 feet) above the ground level. All patients were given oxygen from diagnosis until delivery to the treatment facility, however, all treatment but one was delayed from the onset. Meanwhile, Allan *et al.*, reported three cases of armed forces personnel with DCI that occurred during a commercial flight following artificial depressurization training.^[4] According to that report, the DCI symptoms did not change when the helicopter remained below 304 m (1,000 feet) under the administration of oxygen (15 l/min) and saline. Longphre *et al.*, reported the results of a comparison between treatment with and without normobaric oxygen therapy among 2,231 patients with DCI, because the administration of oxygen may wash out inert nitrogen gas.^[10] According to that report, 47% (1,045) of the patients received oxygen therapy. Persistent complete relief (14%) or improvements (51%) were seen in the patients treated with oxygen therapy alone. After one recompression treatment, 67% of the patients who received oxygen therapy obtained complete relief compared with 58% of the patients not treated with oxygen therapy (odds ratio (OR) = 1.5, 95% confidence interval (CI) = 1.2-1.8). When oxygen therapy was administered within 4 h of surfacing, the OR decreased to 0.50 (0.36-0.69), reducing the number of patients who required treatment with hyperbaric oxygen therapy. Meanwhile, diving induces dehydration.^[11] An experimental study revealed that dehydration significantly increases the overall risk of severe DCI and death.^[12] Clinically, the administration of pre-dive oral hydration decreases the incidence of circulatory bubbles, offering a relatively easy means of reducing the risk of DCI.^[13] Accordingly, in addition to flying at low altitude, providing oxygen therapy and administering fluids may improve the subjective symptoms and/or SpO₂ of patients with DCI after the flight.

There is single report of patients with DCI transported via physician-staffed emergency helicopters.^[4] In the trauma setting, providing early intervention on the scene in the physician-staffed emergency helicopter results in favorable outcomes.^[14,15] In Japan, emergency medical technicians are not allowed to secure the airway via tracheal intubation or the intravenous route, except in cardiopulmonary cases.^[16] In this study, the efficacy of the use of physician-staffed emergency helicopters was not determined; however, the administration of intravenous fluids and/or tracheal intubation by the physician for the patient with DCI may contribute to successful transportation.

The limitations of this study include the retrospective design and small number of cases without a control group. Future prospective studies involving a larger number of cases are needed to further examine this issue.

CONCLUSION

Improvements in the subjective symptoms and/or SpO₂ of patients with DCI may be observed when the patient is transported via helicopter under flights less than 300 m in height with the administration of oxygen and fluids.

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