INTRODUCTION

- Hypobaric (diver) and hypobaric (avatar, astronaut) decompression sickness (DCS) occur significantly, especially in the gas-composition of the decompression phase (9, 31). This necessitates the need for an evidence-based approach to define effective treatment for astronauts.

- Astronauts conducting extravehicular activity (EVA) at remote locations need options for effective treatment, not simply standard of care hyperbaric oxygen (HBO), HBO therapy for divers (1, 2, 4). Using USN Treatment Tables V or VI have allowed the treatment of a single phase (8, 9). This necessitates the need for an evidence-based approach to define effective treatment for astronauts.

- We draw from our own data and from the literature (6) for guidance on effective treatment interventions for hypobaric DCS.

METHODS

- Our data comes from 820 human altitude exposures, mostly at 4.3 psia (222 mmHg), during tests of 40 protocols from 1982 to 2009.

- 119 cases of DCS (25 women and 94 men) with a total of 223 symptoms were available, and 194 symptoms were associated with a resolution pressure.

- Symptom data are specific to conservative NASA denitrogenation protocols (3, 8).

- Symptom location and character, time to symptom onset, and pressure delta (resorption pressure−symptom pressure, psia) for relief of symptom are available in our DCS treatment database.

- Explanatory variables for symptom resolution include gender, age, time to symptom onset, time delay to resorption, embolization as part of exercise at altitude (10-12 days), and initial efforts are to describe symptoms and pressure delta for relief of symptoms.

- We apply multivariable linear regression to identify explanatory variables that influence pressure delta for relief of symptoms.

TABLE 1. Summary Counts by Symptoms

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Symptom-Resolution %</th>
<th>Pressure Delta (psia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>21</td>
<td>62.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Type 2</td>
<td>14</td>
<td>9.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Type 3</td>
<td>11</td>
<td>6.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>100.0</td>
<td>7.2</td>
</tr>
</tbody>
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TABLE 2. Summary Counts by Pressure Resolution

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RESULTS

- Thirty-seven of 194 symptoms (19%) resolved at the test altitude (most often 4.3 psia (222 mmHg)).

- Fifty percent of symptoms resolved after HBO for a persistent symptom at 14.7 psia (760 mmHg), an applied pressure difference of 10.4 psia (538 mmHg) with 50% resolution over a pressure difference of just 3.0 psia (155 mmHg).

CONCLUSIONS

- The application of pressure, the continued use of 100% oxygen at sea level, and the time to affect treatment are considerations for effective treatment of hypobaric DCS.

- Application of pressure during repressurization was effective to resolve the time to affect treatment are considerations for effective treatment of hypobaric DCS.

- The approach must ultimately match the most effective treatment to the anticipated low risk of DCS. Providing standard-of-care hyperbaric oxygen (HBO) therapy for divers (1, 2, 4).

- The approach to treatment is not complete until the offending gas phase is resolved.

- A biophysical model of bubble growth and resolution in tissue will also be assembled into an Astronaut DCS Treatment Database. The goal is to describe hypobaric DCS. Data on 194 symptoms (mostly pain-only) based on 119 cases of DCS from NASA subjects before the mission.

- Providing standard-of-care hyperbaric oxygen (HBO) therapy for divers (1, 2, 4).

- HBO for a persistent symptom at 14.7 psia (760 mmHg), an applied pressure difference of 10.4 psia (538 mmHg) with 50% resolution over a pressure difference of just 3.0 psia (155 mmHg).

- Due to the presence of a constant metabolic gas partial pressure the N2 partial pressure of astronaut and diver bubbles is different.

- The repressurization of the bubbles during the application of pressure while breathing 100% O2 is distanced by the N2 partial pressure gradient between the bubbles and mixed venous blood N2 tension (9).

- In some situations the N2 gradient is greater for the astronaut relative to the diver since the astronaut is breathing 100% O2 for several hours as DCs resolves compared to the diver who is breathing air during and after the dive (22).

- Any treatment protocol significantly influences spacecraft design and acceptable DCS risk.

- Future efforts will define the appropriate treatment pressure and the period of optimum ground level oxygen (5.7) that resolves the greatest number of DCS symptoms following conservative HBO protocols.

REFERENCES


ABSTRACT

INTRODUCTION: Treatment options for decompression sickness (DCS) during Exploration Class extravehicular activity (EVA) must follow an evidence-based approach. The approach must ultimately match the most effective treatment to the anticipated low risk of DCS. Providing standard-of-care hyperbaric oxygen (HBO) treatment at remote locations is costly. All but an optimized treatment plan impacts the mission. METHODS: In-house and external data are available on effective interventions to reduce pain, neurologic, and cutaneous signs and symptoms of hypobaric DCS. Data on 194 symptoms (mostly pain-only) based on 119 cases of DCS from NASA-funded studies of protocols covering from 1982 to 2009 were assembled into an Astronaut DCS Treatment Database. The goal is to describe hypobaric DCS. The approach to treatment is not complete until the offending gas phase is resolved. RESULTS: Thirty-seven of 194 symptoms (19%) resolved at the test altitude (most often 4.3 psia or 222 mmHg). 122 symptoms (63%) resolved during repressurization, 14 symptoms (7%) resolved at site pressure, and 21 symptoms (11%) were persistent at site pressure and resolved during HBO treatment (USN Treatment Table V or VI). Given the lengthy period of denitrogenation provided to NASA subjects before decompression sickness (DCS) differ significantly, especially in the gas composition of the offending gas phase (8, 9). This necessitates the need for an evidence-based approach to define effective treatment for astronauts.

- The application of pressure, the continued use of 100% oxygen at sea level, and the time to affect treatment are considerations for effective treatment of hypobaric DCS.

- Application of pressure during repressurization was effective to resolve the majority of pain-only symptoms given conservative denitrogenation protocols. Statistical and biophysical models have the potential to minimize (optimize) majority of pain-only symptoms given conservative denitrogenation protocols. DCS. Application of pressure during repressurization was effective to resolve the time to affect treatment are considerations for effective treatment of hypobaric DCS.

- The approach must ultimately match the most effective treatment to the anticipated low risk of DCS. Providing standard-of-care hyperbaric oxygen (HBO) therapy for divers (1, 2, 4). Using USN Treatment Tables V or VI have allowed the treatment of a single phase (8, 9). This necessitates the need for an evidence-based approach to define effective treatment for astronauts.

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