COMMENTARY

Titanium in a Hyperbaric Oxygen Environment May Pose a Fire Risk

JONAS HINK AND ERIK JANSEN

HINK J, JANSEN E. *Commentary: Titanium in a hyperbaric oxygen environment may pose a fire risk.* **Aviat Space Environ Med 2003; 74: 1301–2.**

The use of titanium during hyperbaric oxygen therapy may pose a risk of fire. A fresh titanium surface in a high oxygen atmosphere can be a source of ignition. The clinical scenario may be a patient who accidentally breaks his titanium-framed glasses during a hyperbaric oxygen treatment in a monoplace chamber or using an oxygen hood. We recommend some safety precautions to be exercised until consensus standards have been established by the hyperbaric medicine community.

Keywords: safety guidelines.

IT IS WELL KNOWN that hyperbaric chamber operations pose a special fire risk (6). An increased oxygen partial pressure generally increases the flammability of material, and some materials considered non-flammable in normal atmospheric conditions can become flammable in an oxygen-enriched atmosphere such as a hyperbaric air/oxygen environment. Also, the minimum energy required for ignition of combustible materials is lower in a hyperbaric air/oxygen environment than under normal atmospheric conditions (3,5). Therefore, fire-preventing techniques are extremely important when administering hyperbaric oxygen therapy (7).

These preventive measures are aimed at eliminating ignition sources, limiting the combustible materials, and reducing oxygen concentration (6). In the case of monoplace chambers or the use of oxygen hoods, the oxygen fraction is close to 100%, and material selection becomes even more crucial in order to prevent fire. Among the materials used in hyperbaric chambers, metals are normally considered safe (6). However, titanium and its alloys, which are now found in many different consumer products as well as in medical replacement structures, require special attention.

A fresh titanium surface oxidizes instantly when exposed to oxygen, resulting in the formation of a very stable, protective, and strongly adherent oxide film. The oxidation reaction is exothermic, and if the heat given off from the reaction exceeds the rate at which the heat can be conducted away, ignition and burning of the titanium may occur (8). It has been reported that an oxygen partial pressure of 25 ATA (2514 kPa) was required to ignite and burn a fresh titanium surface at room temperature during static conditions (1). However, the results of combustion tests are very configuration-dependent, and such a threshold pressure is not an absolute flammability limit (4). When a test was performed under dynamic flow conditions with pure oxygen streaming past the fresh titanium surface, an oxygen partial pressure of 4.4 ATA (446 kPa) was sufficient to ignite and propagate the reaction (1). In the same study using other configurations, tensile rupture of unalloyed titanium (and hence formation of a fresh titanium surface) in gaseous oxygen at 6.1 ATA (618 kPa) at room temperature was shown to initiate a violent burning reaction. Also, fatigue cracking of a titanium alloy during exposure to gaseous oxygen at 4.4–5.1 ATA (446-515 kPa), at body temperature or less, was shown to induce minute burned spots on the titanium. It was concluded that the use of titanium in oxygen systems should be severely restricted.

In hyperbaric medicine practice, patients are often allowed eyeglasses and jewelry inside the hyperbaric chamber. Due to the growing use of titanium in consumer products, an increasing number of patients can, therefore, be expected to bring titanium items in the form of eyeglasses and jewelry inside the hyperbaric chamber. If these titanium items are only exposed to air in the hyperbaric chamber there is no need for concern, since the studies by Jackson et al. (1) have shown that titanium would not be expected to burn under any pressure when the oxygen concentration is less than 35%. However, if the items are exposed to pure oxygen, which would be the case inside a hyperbaric monoplace chamber or inside an oxygen hood, there is a potential fire hazard, but only if the titanium item breaks and a fresh un-oxidized surface is formed. Although unlikely, it is not impossible that the frames of titanium eyeglasses or a titanium ear-ring might break when manip-

From the The Royal Naval Technical School, Nyholm, Copenhagen, Denmark (J. Hink); and the Hyperbaric Oxygen Treatment Unit, Department of Anaesthesia and Operating Theatre Services, The Centre of Head and Orthopaedics, Copenhagen University Hospital Rigshospitalet, Copenhagen, Denmark (J. Hink and E. Jansen).

This manuscript was received in May 2003; it was revised in July and August 2003. It was accepted for publication in August 2003.

Address reprint requests to: Jonas Hink, M.D., The Hyperbaric Oxygen Treatment Unit (4092), Department of Anaesthesia and Operating Theatre Services, The Centre of Head and Orthopaedics, Copenhagen University Hospital Rigshospitalet, 9 Blegdamsvej, DK–2100 Copenhagen OE, Denmark; hink@dadlnet.dk.

ulated by the anxious patient during hyperbaric oxygen therapy. Titanium watches and medical replacement structures, on the other hand, are not prone to breakage and would not be likely to pose a problem, since unruptured and hence oxidized titanium will ignite and burn only at temperatures above 1200°C (1).

Hyperbaric oxygen therapy is typically performed at a pressure of 2.5–2.8 ATA (253–284 kPa). Due to the risk of oxygen toxicity, the maximum partial pressure of oxygen in clinical hyperbaric chambers is 3 ATA (304 kPa). This value is more than 30% lower than the lowest oxygen partial pressure at which ignition of or burned spots on the titanium were observed in the study by Jackson et al. (1). However, other alloys or different configurations of the titanium than those used in the tests might have lower threshold values for ignition. Moreover, heat given off from the oxidation of a freshly broken titanium surface might not be sufficient for ignition of the titanium itself, but sufficient for ignition of hair or clothing in near contact with the titanium surface.

The NASA Safety Standard for oxygen and oxygen systems (2) states that titanium must not be used with gaseous oxygen at oxygen pressures above 2 ATA (207 kPa). Whether the same safety limits should be implemented in hyperbaric medicine is a relevant and urgent issue. Until further discussions and/or investigations have been performed in order to establish consensus on safety guidelines for titanium in hyperbaric medicine, we recommend the following preventive measures:

1. Breakable titanium and titanium alloy items including eyeglasses and jewelry should not be permitted in a hyperbaric monoplace chamber or in a pure oxygen atmosphere in a multiplace chamber such as an oxygen hood. (This is a very simple safety precaution considering the potential risk.)
2. Titanium and its alloys should not be permitted in oxygen lines and high-pressure systems.

Focus on the above recommended preventive measures should under no circumstances divert the attention from general fire-preventing techniques and more easily ignited and more flammable materials than titanium and titanium alloys.

REFERENCES

1. Jackson JD, Boyd WK, Miller PD. Reactivity of metals with liquid and gaseous oxygen. Columbus, OH: Battelle Memorial Institute. 1963: 1–26. DMIC Memorandum 163. 15-1-1963.
2. National Aeronautics and Space Administration. Safety standard for oxygen and oxygen systems; chapter 3. Washington, DC: NASA; 1996:12. NSS 1740.15. 30-1-1996..
3. National Fire Protection Association. Hyperbaric facilities. In: NFPA 99. Health Care Facilities, Appendix C. Quincy, MA: NFPA; 1999:199.
4. National Fire Protection Association. Material for use in oxygen-enriched atmospheres. In: NFPA 53. Recommended practice on materials, equipment, and systems used in oxygen-enriched atmospheres, Appendix F. Quincy, MA: 1999: 45.
5. National Fire Protection Association. Materials selection. In: NFPA 53. Recommended practice on materials, equipment, and systems used in oxygen-enriched atmospheres, chapter 3. Quincy, MA: 1999:6.
6. National Oceanic and Atmospheric Administration. Hyperbaric chambers and support equipment. In: Joiner JT, ed. NOAA Diving Manual, chapter 18. Flagstaff, AZ: Best Publishing Company; 2001:13.
7. Sheffield PJ, Desautels DA. Hyperbaric and hypobaric chamber fires: a 73-year analysis. Undersea Hyperb Med 1997; 24:153–64.
8. Titanium Metals Corporation - TIMET. Corrosion resistance of titanium. Denver, CO: TIMET; 1997:20.