Dysbarism: A Jet Age Problem of All Physicians*

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With the attention of the world focused on space efforts and the appearance of commercial jet aviation, medical subjects, which formerly concerned only aviation medicine specialists, now have become of considerable interest to all physicians. One example of the degree of interest has been the establishment of the Committee on Aerospace Medicine by the American College of Chest Physicians.

Much attention has been given to the problem of altitude hypoxia in the event of cabin depressurization of commercial jet aircraft, and the emergency oxygen equipment, which is available in the aircraft can be used to minimize oxygen want. However, little has been published about the adverse effects of reduced barometric pressure, per se, except in physiology or aviation medicine journals. The adverse effects of changes in barometric pressure are known as dysbarism. When the differential is between the pressure at sea level and greater pressure, these adverse effects are commonly called caisson disease, long a problem for deep sea divers. Altitude dysbarism occurs when barometric pressure is less than that at sea level inasmuch as barometric pressure decreases progressively with increase in altitude. For example, the mass of air which presses down upon us at sea level weighs approximately twice as much as that at 18,000 feet and approximately three times as much as that at 27,500 feet altitude.

Two consequences of the physical properties of gases are important to recall. First, a volume of gas contained in an elastic membrane, such as a balloon, will increase in size as the surrounding (ambient) barometric pressure is reduced. Second, the solubility of a gas in solution is proportional to the partial pressure of that gas in the surrounding atmosphere, and when this pressure is reduced, the dissolved gas will come out of solution and tend to form bubbles. An example of this phenomenon is experienced daily when the top is removed from a bottle of soda pop. Probably these two physical properties of gases are the most significant causes of dysbarism, which manifests itself in several ways (Table 1).

Body cavities which are open to the outside, either constantly or intermittently, contain gases. If with changes in altitude the communication is maintained, air will escape or enter these spaces as the enclosed gases contract or expand, and no pressure will be built up. Upon ascent to altitude, it is a common experience for the gases within the gastrointestinal tract to expand and thereby enlarge the abdominal girth until either flatus or gaseous eructation causes deflation. When these adjustments do not occur, abdominal pain of significant severity can result. Either the amount of expanded gas within the alimentary tract must be reduced or the individual must descend to an altitude of greater ambient barometric pressure before he can obtain relief.

Any condition which will cause inflammation or edema of the mucous membranes may cause blockage of the eustachian

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*This paper represents the personal viewpoints of the authors and is not to be construed as a statement of official Air Force policy.
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ian tubes or sinus orifices. Thus, upon a rapid change of altitude, equalization of the pressure between the air in the middle ear or sinuses and the atmosphere will be delayed or prevented, causing severe symptoms of aerotitis media or aerosinusitis.

By popular usage, the term, dysbarism, is usually restricted to those conditions which result from the evolution of gases. The most frequent syndrome is known as the bends. This term is derived from similar joint, bone and muscle symptoms reported in caisson disease. Here the principal manifestations are deep boring aches or pains in the bones or muscles around the peripheral joints. They can vary in severity from mildly noticeable discomfort to pains of such intensity that the patient must descend from altitude because of the intolerable severity. When the pains are severe, there is a tendency to splint the extremity. They may also be accompanied by evidences of primary shock and, eventually, neurocirculatory collapse. The incidence of bends tends to be proportional to the duration of altitude exposure. However, it seldom occurs at altitudes below 25,000 feet although it has been reported at an altitude as low as 17,000 feet.¹ The cruising altitudes of jet aircraft are well above these levels, and depressurization could expose passengers to the dangers of bends. Older and more obese individuals are prone to develop this syndrome. Performance of physical activity at altitude tends to precipitate this reaction or, if it is present already, causes an increase in severity. Almost invariably the discomfort will disappear during or after descent to lower altitudes.

Another distressing manifestation of dysbarism is chokes. This syndrome is characterized by substernal distress (tightness or pain), a nonproductive cough, difficulty in breathing, and an exacerbation of both the substernal distress and the cough when attempts are made to take a deep breath. The incidence of this symptom complex is approximately one-tenth that of bends. However, it may accompany bends or it alone may be associated with neurocirculatory collapse. Generally, the factors which predispose the individual to bends similarly affect chokes. However, because of the lower incidence of chokes, direct causal relationships are more difficult to prove.²

The occurrence of bends and chokes should alert the physician to the possibility of the most life-threatening manifestation of dysbarism, neurocirculatory collapse. Fortunately, this complication occurs only infrequently. Adler³ reported 400 cases in approximately one million altitude exposures to more than 30,000 feet with only seven fatalities. However, Berry and Smith⁴ reported 62 cases during actual flight in a 19-month period of extensive Air Force operations. A review by Malette et al.⁵ of 35 cases, 16 of which were fatal, indicates that neurocirculatory collapse can be quite serious and carries a definite threat to life. The majority of patients demonstrate components of both neurologic and circulatory involvement. Some show only circulatory or neurologic signs, but more frequently evidence of circulatory inadequacies of some degree becomes manifest, and it is this malfunction which is life-threatening.

Signs of neurologic involvement are protean. Visual disturbances, such as scotomata, hemianopsia or diplopia occur most frequently. Paresis, paralysis, or abnormal reflexes, as well as dysesthesia, aphasia, or reduced level of consciousness may be present. It is not uncommon to find signs which change in location and intensity upon reexamination. Even primary shock with its bradycardia, hypotension, pallor, sweating, and fainting can be secondary to dysfunction of the autonomic nervous system. Unfortunately, this is followed frequently by secondary shock with severe hypotension, tachycardia, and a reduced circulating plasma volume.

While the majority of evidence to date indicates that bends, chokes and neurocirculatory collapse are conditions which result from the evolution of gases from the tissues and circulating fluids, this evidence is all indirect because of the limitations encountered in utilizing patients as experi-
mental models. There are proponents of vasospasm and blood sludge theories. Probably vasospasm can play a secondary, contributing role by means of reflex spasm resulting from intra- or extra-vascular bubbles. The common denominator is local ischemia from a variety of causes. Intravascular gas bubbles have been seen experimentally in animals exposed to the low pressure of exceedingly high altitude or to high pressure levels with subsequent rapid decompression. The one piece of evidence which lends the greatest weight to the bubble theory is the protection which is afforded against bends by denitrogenization. This is accomplished either by the breathing of 100 per cent oxygen and consequent leaching of nitrogen from the body prior to high altitude exposure or by the exposure of the subjects to moderate altitudes for several days prior to ascent to high altitudes. In the latter instance, the body can eliminate a considerable amount of nitrogen slowly as a result of the reduced partial pressure of nitrogen in the air at moderate altitudes. Nitrogen is inert in the body, being present in highest concentration in the fat tissues. Perhaps this helps to explain the proclivity of overweight individuals to dysbarism. The majority of cases which have come to necropsy have shown fatty degeneration of the liver. The presence of fat emboli in the lungs and other tissues is an inconstant but striking finding. Hickey et al. postulate that the nitrogen in the fat cells of the liver tends to form intracellular bubbles, rupture the cells, and liberate the fat into the liver sinusoids and, thus, into the circulation. Therefore, the presence of fat emboli appears to be the result of nitrogen release.

The aphorism, "an ounce of prevention is worth a pound of cure," certainly applies to dysbarism. Denitrogenization as a method of prevention has been discussed earlier. Another method of preventing this syndrome is the pressurization of aircraft cabins so that the occupants are exposed to significantly lower atmospheric pressures than those of the high altitude at which the plane is flying. Only if pressurization fails does the sceptor of dysbarism loom. It is important to remember that the emergency use of oxygen will not prevent the onset of dysbarism during high altitude exposure. Animal experimental research with intravascular administration of agents which reduce surface tension indicates that this approach may be of some value in protection from aero-emboli. However, as yet, this is not applicable clinically. Whether or not an individual who has suffered from severe dysbarism is more prone to recurrences than to the initial attack is still unknown. In view of this lack of information, Berry and King recommend that such individuals in the Air Force be restricted to altitudes of less than 20,000 feet.

The occurrence of any symptom of dysbarism should alert the physician. Symptom-free periods between the return to ground level and the onset of serious neurocirculatory decompensation have been reported. It is recommended that the patient be observed and that vital signs be checked for at least two hours after return to ground level. In treating neurocirculatory collapse, Malette et al. recommend that the hematocrit be utilized to estimate the reduction in the circulating plasma volume. They have emphasized that severe collapse occurs rapidly when compensation for a markedly reduced volume suddenly becomes inadequate. To prevent this deterioration, they recommend early, adequate replacement therapy for correction of reduced plasma volume. Usually oxygen is administered, and other general supportive measures are taken. One case report revealed the rapid resolution of a life-threatening situation when the patient was placed in a recompression chamber and exposed to pressures greater than one atmosphere. This was an attempt to force any liberated nitrogen back into solution. It is an interesting approach which could be worth a try if the facilities are available.

**Summary**

1. With increased utilization of commercial jet aircraft, the possibility of loss of
cabin pressurization and subsequent high altitude exposure of the occupants increases. The adverse effects of exposure to the reduced barometric pressure of high altitude, per se, has not been publicized. Therefore, it becomes important for physicians to become familiar with the manifestations of altitude dysbarism.

2. The effects of reduced barometric pressure result from the gases trapped within the body cavities or the evolution of gases from the liquid phase within the tissues or body fluids.

3. In general, trapped gases can be quite discomforting, but not usually dangerous unless the pressures generated are sufficient to cause the rupture of a hollow viscus, and this is quite rare. Generally, re-establishment of a patent foramen between the cavity and the atmosphere will result in relief.

4. However, the problems that arise when the nitrogen in the body fluids or fat tissue comes out of solution can be life threatening. Since this is more apt to occur in older and more obese individuals, a significant percentage of the flying public can be considered "dysbarism prone." Here the manifestations are bends (with extremity pains), chokes (with the respiratory distress, substernal pain, and dry cough) and neurocirculatory collapse. Neurocirculatory collapse may present a bizarre pattern of neurologic aberrations which resolve if the patient recovers. When circulatory failure becomes evident, mortality can be expected to be high and intensive care is essential.

5. Since neurocirculatory failure has been reported to develop rapidly after a relatively symptom-free period, it is advocated that individuals who experience any manifestation of dysbarism be observed for at least two hours after removal from altitude exposure.

6. Generally treatment is supportive and includes the administration of oxygen. However, it appears that the early correction of reduced circulating plasma volume is also essential.

Resumen

1. Con el uso creciente de los aviones comerciales de retroimpulso aumenta la posibilidad de pérdida de la presión artificial en la cabina en las altitudes elevadas, con exposición de los ocupantes a ese cambio. No se ha dado publicidad a los efectos adversos que tal exposición, a bajas presiones en la altitud, por sí sola puede producir.

Por esto es importante para los médicos el que se familiaricen con las manifestaciones del disbarismo de altitud.

2. Los efectos de la presión barométrica reducida son consecuencia de los gases atrapados dentro de las cavidades del cuerpo o del desprendimiento de gases de los líquidos dentro de los tejidos o los líquidos del cuerpo.

3. En general los gases atrapados pueden causar franca incomodidad, habitualmente no peligrosa a menos que las presiones desarrolladas sean suficientes para producir la ruptura de una víscera hueca, y esto es bastante raro. Generalmente, al restablecerse el paso por la vía natural de la cavidad hacia la atmósfera, hay alivio.

4. Sin embargo, los problemas que resultan cuando el nitrógeno en los líquidos o en la grasa del cuerpo deja de estar disuelto pueden amenazar la vida. Puesto que esto puede ocurrir más fácilmente en las gentes de edad mayor y en los obesos cierto porcentaje de los viajeros por aire pueden considerarse "propensos al disbarismo."

Las manifestaciones en ese caso serían: "benda" (con dolores en las extremidades), sensación de ahogo (con molestias respiratorias, dolor subesternal y tos seca) y colapso neurocirculatorio. Este último puede presentar un aspecto extraño de aberraciones neurológicas que se resuelven si el enfermo se recupera.

Cuando la insuficiencia circulatoria se hace evidente, es de esperar una elevada mortalidad y un cuidado intenso debe considerarse esencial.

5. Ya que el trastorno neurocirculatorio se ha dicho que se desarrolla rápidamente después de un período relativamente libre de síntomas, se aconseja que los individuos que experimentan cualquier manifestación de disbarismo sean observados por lo menos dos horas después de la exposición a la altitud.

6. En general, el tratamiento es de sostén e incluye la administración de oxígeno. Sin embargo, parece que la temprana corrección del plasma reducido circulante es también esencial.

Zusammenfassung

1. Mit zunehmender Ausnutzung des zivilen Düsenluftverkehrs wächst die Möglichkeit, daß der Kabinendruck verloren geht und die Möglichkeit zunimmt, daß die Insassen infolggedessen großen Höhendifferenzen ausgesetzt sind. Die Nebenwirkungen der Exposition von reduzierten
Barometerdruckwerten in großen Höhen sind als solche noch nicht veröffentlicht worden. Es wird daher für die Ärzte bedeutungsvoll, mit den Manifestationen der Höhenunverträglichkeit vertraut zu werden.

2. Die Wirkungen eines reduzierten Barometerdruckes ergeben sich aus den eingeschlossenen Gasen innerhalb der Körperhöhlen oder der Entwicklung von Gasen aus ihrer Flüssigkeit innerhalb der Gewebe oder Körperflüssigkeit.

3. Im allgemeinen können die eingeschlossenen Gasmenge recht quälend und unbehaglich wirken, jedoch für gewöhnlich nicht gefährlich werden, außer, wenn die entstandenen Druckwerte ausreichend sind, um eine Ruptur der Hohlorgane zu bewirken, und dies ist ziemlich selten. Im allgemeinen ist die Schmerzbeurteilung infolge einer offenen Verbindung zwischen Hohlraum und Atmosphäre das Ergebnis einer Besserung.

4. Im Gegensatz dazu können die Probleme, die entstehen, wenn der Stickstoff in den Körperflüssigkeiten oder Fettgeweben aus einer gelösten Form hervorgeht, lebensbedrohlich wirken. Da dies öfter vorkommen kann bei älteren und mehr korpulenten Personen, so kann ein beträchtlicher Anteil der die Dysfunktionen benutzenden Öffentlichkeit als anfällig für Höhenunverträglichkeit angesehen werden. Hier sind die Erscheinungen die Caisson-Krankheit (mit Extremitäten- schmerzen), Luftembolie (mit respiratorischer Atemnot, substernalen Schmerzen und trockenen Husten) und ein neuro-zirkulatorischer Kollaps. Der neuro-zirkulatorische Kollaps kann eine bizarre Vielzahl neurologischer Störungen bewirken, die sich jedoch von selbst beheben, wenn sich der Patient erholt. Wenn eine zirkulatorische Insuffizienz augenfällig wird, muß man mit Mortalitätsfällen rechnen, und eine intensive Betreuung ist wesentlich.

5. Da man damit rechnen kann, daß ein neuro-zirkulatorisches Versagen sich rasch entwickelt nach einer relativ symptom freien Periode ist es zu empfehlen, daß Personen, die erfahrungsgemäß Manifestationen einer Höhenunverträglichkeit zeigen, für mindestens 2 Stunden nach Rückkehr aus großen Höhen unter Beobachtung bleiben.

6. Im allgemeinen ist die Behandlung eine unterstützende und umfaßt auch Sauerstoffbehandlung. Es erscheint jedoch eine frühzeitige Korrektur des reduzierten zirkulatorischen Plasma volumens ebenfalls sehr wesentlich.

References


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