CHAPTER 3

'EXPLOSIVE'* DECOMPRESSION INJURIES

However remote the possibility might be, astronauts will always face the potential hazard of 'explosive' decompression during space missions. Such an extremely rapid reduction of the ambient atmospheric pressure of a spacecraft cabin might be caused by the penetration of the cabin wall by a large meteoroid, or by a structural failure resulting from a landing accident on a moon or planet. A space suit might receive a large perforation from accidental contact with a sharp stationary object, or with a tool or other piece of movable extravehicular equipment during an extravehicular operation.

Theoretical analyses of 'explosive' decompression transients have been presented by Haber and Clamann [8] and others [12, 13, 15]. These analyses indicate that the possible injuries from an 'explosive' decompression are determined by the change in absolute pressure, the ratio of the initial to the final ambient atmospheric pressure and the rate of decompression. It is important to remember that one of the main factors which determines the rate of decompression is the ratio of the volume (V) of the spacecraft or space suit to the effective area (A) of the decompression orifice. This ratio becomes the time characteristic (t_c) of decompression when the velocity of sound (C) is included in the relationship

$$t_c = \frac{V}{A \cdot C}$$

for the particular volume and decompression orifice under consideration. It is noted that the time characteristic is independent of pressure.

During 'explosive' decompression, an exposed astronaut might sustain injuries inflicted internally by the rapid expansion of gases in gas-containing organs, especially the lungs. A variety of mechanical injuries (Chapter 14) might be inflicted if he is displaced or struck by displaced objects as the cabin air rushes toward the decompression orifice. This type of injury might also be produced by the factor which caused the decompression, such as a landing accident or meteoroid. After 'explosive' decompression, acute hypoxia (Chapter 1) and ebullism (Chapter 2) will probably be experienced.

* It is noted that for thermodynamic reasons, the flow of gases through an opening in a spacecraft cabin wall or space suit cannot exceed the speed of sound. On the other hand, one of the physical characteristics of an explosion is that its air blast is supersonic. Therefore the term 'explosive' decompression is actually a misnomer. However, it is commonly used to refer to extremely rapid decompressions occurring in less than 1 sec [2].

For references see p. 36

D. E. Busby, *Space Clinical Medicine*

This chapter is mainly concerned with the pathophysiology, clinical manifestations, diagnosis and treatment in space of possible internally inflicted 'explosive' decompression injuries. The most likely externally inflicted injuries are mentioned, but discussion of their treatment is reserved for Chapter 14.

A. Internally Inflicted Injuries

1. *Pathophysiology*

Since the solid and liquid constituents of the body are not deformed by changes of ambient atmospheric pressure, only those organs which contain appreciable amounts of free gas are immediately affected by 'explosive' decompression. Whenever expanding intracorporeal gases cannot escape readily during an 'explosive' decompression, they will exert pressure and so stretch surrounding tissues. Due to their fragile structure and the large amount of gas they contain, the lungs are more susceptible to injury by overpressure than the abdominal organs [13].

It has been established experimentally that if the intact mammalian lung-thorax system is permitted to expand passively, the lung structure will disrupt at pressure differentials across the lungs and chest wall of about 80 mm Hg [1, 17]. Also of interest is the fact that the pressure differentials of more than 150 mm Hg are frequently tolerated in the act of coughing, during which active muscular effort actually reduces lung volume by compressing its gas content [13].

Fortunately the probability that an astronaut's respiratory passages could be obstructed and hence overdistended by trapped intrapulmonary gases at the instant of an 'explosive' decompression is very remote. Moreover, it appears that patent airways will allow an adequate escape of expanding gases under all but the most extreme of conditions [13]. These conditions can be fulfilled if the difference between the decompression time characteristic of the spacecraft cabin or space suit and that of an astronaut's respiratory passages is such that a transient pressure differential of a sufficient magnitude builds up between the astronaut's lungs and his ambient atmosphere. Since the volume of the lungs varies with respiration, it is apparent that the time characteristic of the respiratory passages also varies with the phase of expiration. The transthoracic pressure differential for patent airways would therefore be greatest when decompression occurs at the time of full inspiration.

The time characteristic of 'explosive' decompression required for injury or death is unknown for humans [15]. The results of animal studies, reviewed by Luft [13], indicate that a cabin V/A ratio of about 1.2 (m^3/m^2), or a time characteristic of about 3 millisec, is associated with a 50% mortality. If such data can be reasonably extrapolated to man, only the apparently uncomplicated exposures of Sweeney [18], who had the cabin V/A ratio at about 1 (m^3/m^2), have been within the expected lethal range. It has been noted, however, that even if these human decompressions occurred with the respiratory passages closed and the lungs at mid-respiratory volume, the change in ambient atmospheric pressure would have been insufficient, despite the low V/A ratio, for a critical overpressure of about 80 mm Hg to be produced in the lung [13].