A THERMODYNAMIC AND KINETIC APPROACH

TO

DECOMPRESSION SICKNESS

by


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Summary

A THERMODYNAMIC AND KINETIC APPROACH TO DECOMPRESSION SICKNESS

An hypothesis has been developed to explain the mechanism and kinetics of the occurrence of marginal symptoms of decompression sickness. The approach is essentially quantitative, all expressions being derived from fundamental physical and physiological parameters.

The hypothesis attempts to offer a more comprehensive mechanism for processes leading to the onset of pain than do existing theories. It deviates widely from the latter on several major issues by including postulations of:

1. Random nucleation for gas phase separation in tissue.
   This is adopted in preference to the concept of a metastable limit to the supersaturation of tissue by gases which is effectively implied by conventional methods of calculation. Experimental evidence is provided for the random nature of cavitation at liquid-liquid interfaces.

2. Tissue as a two-phase system of irregular internal boundaries. This has provided a satisfactory transport model for describing the transient uptake of gases which is consistent with histological considerations. Data for assessment has been obtained experimentally from the exchange of inert substances in the same tissue both with and without circulation. The relevant model for predicting the occurrence of symptoms is taken as the 'worst possible case'. This refers to considerations of both the random geometry of tissue and the statistical thermodynamics of phase separation.

3. Diffusion as the rate-limiting process in this particular 'worst possible' case.

4. The driving force for inert gas elimination following phase separation to be an 'inherent unsaturation' arising in tissue by virtue of metabolism and the physico-chemical properties of blood.
Experimental evidence is provided for the existence of this 'inherent unsaturation', and its predicted tendency to increase with either oxygen enrichment of inhaled gas or with increased pressure. The latter is the chief source of deviation from existing predictions of the optimal decompression format. Much deeper staging of a diver is suggested. This is shown to be consistent with the purely empirical format devised by pearl divers operating in Australian coastal waters.

The same expressions provide a better quantitative correlation of fifteen different sets of published practical data than do the existing theories. Data analysed include aerial decompressions, repetitive dives, and dives where there is oxygen enrichment, helium inhalation, titrated staging, no staging, working conditions, resting conditions, an effectively infinite exposure, etc.

The hypothesis also appears to be qualitatively more consistent with some twenty-three essentially different aspects of decompression sickness.

A pneumatic analogue has been devised to analyse dives according to the hypothesis. It can simulate radial diffusion and can automatically account for the effects of a phase change upon inert gas transport. Excessive mathematical complexity has been similarly avoided by using a thermal analogue to predict the optimal deployment of decompression time.

These optimisations have shown a saving of at least 35% in the decompression time for equal safety following a dive of 40 minutes at 150 feet, relative to standard tables tested concurrently in vivo. These comparative trials offer the strongest support for the reality of the mathematical expression and synthesis of the hypothesis.