THE LAW OF IMPEDANCE PNEUMOGRAPHY*

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Abstract—The impedance coefficient in ohms/litre obtained by means of bipolar impedance pneumography exhibits an inverse relationship with body weight in kilogrammes; this relationship appears valid on an inter-species basis and is probably also true from an intra-species point of view. The relationship is linear on log-log paper and nearly hyperbolic on a linear scale. A statistical regression analysis produced the expression \( \log(\Delta Z/\Delta V) = 2.656 - 1.08 \log W \) with a Standard Error of Estimate of 0.24 and a correlation coefficient \( r = -0.976 \), where \( \Delta Z/\Delta V \) is the impedance coefficient in ohms/litre and \( W \) the body weight in kilogrammes. The impedance coefficient per kilogramme, obtained as the derivative of the expression above, is given by \( \log(490 - 2.08 \log W) \) and describes with accuracy the change in sensitivity with different weights. For low values of body weight \( W \), the impedance coefficient is very high; for high values of \( W \), the impedance coefficient is very low and, beyond 1000 kg, negligible signals are to be expected. This observation was verified in the elephant.

INTRODUCTION

Direct spirometry, although it can be easily applied and accurately calibrated, has the disadvantage of partially obstructing the airway. In many subjects (e.g., critically ill patients, newborn infants and small animals) such loading of the respiratory system may be unacceptable, in which circumstance impedance pneumography (GEDDES et al., 1962) can be employed. Calibration of an impedance pneumograph record requires a volume-measuring instrument (BAKER et al., 1965). This procedure leads immediately to the concept of an impedance coefficient which is defined as the change in impedance per unit volume of air respired. The impedance coefficient \( \Delta Z/\Delta V \), is usually expressed in ohms/litre.

The magnitude of the impedance coefficient \( \Delta Z/\Delta V \) varies with electrode location, body weight and species (BAKER et al., 1965, 1966; GEDDES and BAKER, 1968; BAKER and GEDDES, 1970; HUGGINS et al., 1971), tending to be higher for lighter subjects and lower for heavier subjects. It is the object of this paper to investigate the relationship between \( \Delta Z/\Delta V \) and body weight.

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\[ \frac{\Delta Z}{\Delta V} \text{ in human subjects} \]

\[ \frac{\Delta Z}{\Delta V} \text{ in the dog} \]

\[ \text{ohms/litre of air breathed} \]

Fig. 1. Change in thoracic impedance with respiration in man and dog.
weight \( (W) \) on an interspecies basis, and to show quantitatively the inverse relationship between the impedance coefficient and body weight. This relationship is designated 'the law of impedance pneumography'. The electrode location is particularly important when using the bipolar impedance method to measure respiration. This point is illustrated by Fig. 1 which shows the impedance coefficient \([\text{ohms/litre}]\) in human subjects of differing body weights along with data from a typical 15 kg dog. In the case of thin human subjects (ectomorphs), it is clear that the largest \( \Delta Z/\Delta V \) is obtained with a pair of trans-chest electrodes placed along mid-axillary lines at the level of the seventh pair of ribs. In the case of heavy subjects (endomorphs) the impedance coefficient is less and there is no optimum location for the maximum value. In the dog, because the chest is thin, the impedance coefficient is larger and there is an optimum location for the trans-chest electrodes to obtain the highest impedance coefficient; as in the thin human, it occurs at the level of the seventh pair of ribs.

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**Fig. 2.** Calibration of impedance pneumogram from an armadillo with a syringe. Above: respiratory signal and calibration. Below: calibration curves relating ohms, centimetres of pen deflection and cubic centimetres of air.