SHORT COMMUNICATION

THE POINT OF ONSET OF 'AIRWAY CLOSURE' MEASURED WITH ARGON AND NITROGEN: A COMPARISON OF RESULTS OBTAINED BY TWO METHODS

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SUMMARY

1. The point of onset of 'airway closure' has been determined by simultaneous analysis of expired argon and nitrogen in twenty-five subjects studied in the sitting and supine postures.

2. Estimates of 'closing volume' derived from nitrogen analysis were less than those derived from argon analysis, the difference being partly attributable to a less readily defined inflexion in the record of expired nitrogen.

3. The relationship between the two estimates of 'closing volume' was linear and was not influenced by the age or posture of the subjects.

4. It is valid to use nitrogen as the tracer gas for the measurement of 'airway closure', despite the difference in the formation of the inspired bolus, but results should be compared with normal values established separately for this gas.

Key words: 'closing volume', dependent 'airway closure', nitrogen boluses, argon boluses, normal subjects.

Dollfuss, Milic-Emili & Bates (1967) described a method for determining the lung volume at the point of onset of closure of gravitationally dependent airways, 'closing volume' (CV), by analysis of the expired gas following the inspiration of a bolus of $^{133}$xenon. Other inert gases, such as argon (Jones & Clarke, 1969) and nitrogen (Anthonisen, Danson, Robertson & Ross, 1969), have since been used. Variation in CV with age and posture (Anthonisen et al., 1969; Leblanc, Ruff & Milic-Emili, 1970) and the effect upon gas exchange of the relationship between CV and functional residual capacity (FRC) (Craig, Wahba, Don, Couture & Becklake, 1971) have been studied.

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Nitrogen may become the tracer gas of choice for studies of the population or at the bedside, because portable analysers are available. As the procedure for determination of CV with nitrogen varies from that using argon or xenon, it is important to establish that results obtained with nitrogen are comparable with those obtained with other gases. We describe here a comparison of measurements of CV obtained simultaneously with argon and nitrogen.

**SUBJECTS AND METHODS**

Twenty-five subjects, seventeen male and eight female, aged 19–63 years, were studied. All gave their consent after the nature of the procedure had been explained to them. None had respiratory symptoms or a history of chronic respiratory disease, but no account was taken of smoking habits. In one subject the forced expiratory volume in 1 s (FEV₁) was just more than 1 standard deviation (SD) below the predicted value given by Cotes (1968). In other subjects the FEV₁ was within or above 1 SD from the predicted value.

‘Closing volume’ was measured by the method of Jones & Clarke (1969) for argon and of Anthonisen et al. (1969) for nitrogen, with modifications detailed below. The experimental basis for the methods is given by Milic-Emili, Henderson, Dolovich, Trop & Kaneko (1966) and Dollfuss et al. (1967).

Gas flow was measured with a pneumotachograph (Fleisch) and volume obtained by integration. Gas sampled at the mouth was analysed simultaneously for argon and nitrogen by a mass spectrometer (AEI-GEC, model MS 4). Argon and nitrogen concentrations were simultaneously displayed on the y axis of a storage oscilloscope (Tektronix) against volume on the x axis, and tracings were made. All the variables were also recorded against time on an eight-channel recorder (Elema-Schonander).

In each manoeuvre the subject expired to residual volume (RV). A 120 ml bolus of argon was injected into the gas at the mouth by a spring-loaded piston, and the subject was simultaneously connected to a bag of oxygen. The nitrogen in the apparatus dead-space (60 ml) and the airways then formed the nitrogen bolus. The subject inspired immediately, slowly and evenly to total lung capacity, at a flow rate of approximately 0·5 litre/s, and without pause expired similarly to RV.

Simultaneous analysis of expired argon and nitrogen showed alveolar plateaux (phase III) with cardiogenic oscillations (Fowler & Read, 1961) followed by a terminal rise (phase IV) (Dollfuss et al., 1967). When a straight edge was laid along the alveolar plateau, the point at which the tracing definitely and finally moved upwards was taken as the onset of phase IV. ‘Closing volume’ was defined as the volume from this point to RV and was expressed in litres at ambient temperature and pressure, saturated (ATPS). In this way CV is expressed as a division of vital capacity rather than as the division of total lung capacity which would have been obtained if the volume from the onset of phase IV to zero lung volume had been measured. Manoeuvres which did not conform to the above procedure, or in which the onset of phase IV was not clear, were rejected. Three to six satisfactory measurements were obtained from each subject in both sitting and supine postures.

The delay time of gas analysis was approximately 0·2 s. No allowance was made for this on the oscilloscope record, although the pens of the recorder were appropriately offset. The comparison of estimates here described should be unaffected, as the delay was the same for both gases.
'Airway closure' measured by two methods

RESULTS

The 166 acceptable manoeuvres (eighty-six sitting and eighty supine) were analysed. The relationship between pairs of estimates of CV derived from argon and nitrogen is shown in Fig. 1, together with the line of closest fit for the group as a whole. The equation of the line was:

\[ y = 0.058 + 0.815x \]

with SD from regression ±0.157 litre at ATPS. This line did not differ significantly from the lines of closest fit relating measurements made either in sitting or supine postures. Six points lay outside 2 SD from the regression line; they were obtained in four subjects, in all of whom other measurements fell within 2 SD from the regression line. If, in each subject, the mean of all manoeuvres in each posture is taken, the regression coefficient (0.820) of the line of closest fit relating the mean values is similar to that for the individual manoeuvres, but the SD from the regression line is decreased to ±0.119 litre at ATPS.

Increasing age did not affect the relationship between the two estimates, for the correlation between age and the mean difference between pairs of estimates in each subject was not
statistically significant either in the sitting \( (r = 0.276, P > 0.1, n = 25) \) or supine \( (r = -0.057, P > 0.1, n = 25) \) posture.

**DISCUSSION**

When 'closing volume' is measured by the nitrogen method, the nitrogen in the mouthpiece and the anatomical dead-space forms the bolus. In contrast to argon and xenon, there is already a high concentration of nitrogen in the residual gas in all parts of the lung, and the concentration gradient of nitrogen produced between different lung regions is therefore less than that produced with argon or xenon. The terminal rise on the expired-nitrogen trace is therefore less high relative to the height of the alveolar plateau and the cardiogenic oscillations are less marked. The inflexion between phase III and IV for nitrogen is thus less easily recognized than that for argon. There may thus be a systematic tendency to read the inflexion point later when nitrogen is used, which may partly explain the difference between the two estimates of CV.

Although much of the nitrogen bolus lies in the airways at RV and is nearer to the alveoli than boluses injected at the mouth, the same CV should be measured if any gradient of concentration is produced in the lung, that is if any of either bolus enters some alveoli before the gravitationally dependent airways open. We can therefore see nothing inherent in the different formation of the nitrogen and argon boluses to account for the difference between the estimates.

The finding of a systematic discrepancy between the two estimates indicates that measurements of CV should be compared with normal values obtained with boluses of the same volume and gaseous composition. Tracings of expired argon are easier to analyse, but the nitrogen method may have the advantage of greater convenience in clinical work.

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**REFERENCES**


