Variation between observers in the estimation of airway resistance and thoracic gas volume

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Lord, P. W., Brooks, A. G. F., and Edwards, Janet M. (1977). *Thorax*, 32, 67-70. Variation between observers in the estimation of airway resistance and thoracic gas volume. Variations in the estimation of airway resistance (R_{aw}) and thoracic gas volume (V_{tg}) made by different observers using body plethysmography have been investigated. Five observers determined R_{aw} and V_{tg} in normal subjects using prerecorded signals so that intrasubject variations were eliminated. The slopes of the oscillograph tracings required to make the determinations were assessed using a cursor and a scale fitted to the oscilloscope. Significant and consistent differences in R_{aw} determined by different observers were found, with a mean range of 37%. Great care should therefore be taken when comparing results obtained by different observers. The variation between observers measuring V_{tg} was significant and consistent but of much smaller magnitude than was the case for R_{aw} , having a mean range of 12%.

In the course of experiments (Lawther *et al.*, in preparation) we have seen that there are significant and substantial inter-observer variations in the measurement of airway resistance (R_{aw}) and thoracic gas volume (V_{tg}) by whole body plethysmography using the methods described by Comroe *et al.* (1959). Significant differences in R_{aw} as measured by two observers of the order of $0.005 \text{ kPa l}^{-1} \text{ s}$ have been noted by Guvatt *et al.* (1967). Experiments have also shown that there is a tendency to estimate progressively lower values of R_{aw} in successive measurements (Lawther *et al.*, 1973; Lawther *et al.*, in preparation). In a comparison of measurements of R_{aw} obtained simultaneously by an automatic method and by an experienced observer (AB) it was shown that this tendency was more likely to be due to a perceptual error made by the observer than to genuine changes in R_{aw} (Lord and Brooks, 1977). The experiment reported here was performed in order to investigate more fully the magnitude of observer differences and to see if the decline between successive readings could be demonstrated with other observers. Since R_{aw} varies considerably within individuals both during the day and between different days (McDermott, 1966; Zedda and Sartorelli, 1971; Hruby and Butler, 1975), the comparisons reported here were made by record-

ing the signals output from the plethysmograph and replaying them to each of the observers under test so that variations within subjects would be eliminated and so that each observer assessed R_{aw} and V_{tg} from identical signals.

Method

As part of another experiment (Lord and Brooks, 1977), R_{aw} and V_{tg} were assessed by constant volume plethysmography (DuBois *et al.*, 1956a, b). The electrical signals representing plethysmograph pressure, airflow, and mouth pressure, which are normally displayed in pairs on the axes of an oscilloscope, were recorded using two channels of a four-channel Hewlett Packard 3960 analogue tape recorder. The signals were recorded at 2.38 cm sec^{-1} . The plethysmograph pressure signal was passed through a high-pass filter (cut-off at 0.05 Hz , 12 dB/octave) before recording to suppress slow drift due to thermal changes in the plethysmograph. Signals were recorded from 12 subjects on five occasions and each time 10 successive measurements of R_{aw} and V_{tg} were made. Seven panting respirations were allowed for determining R_{aw} and seven for V_{tg} . The subjects were instructed to pant with a frequency of 2 Hz and with a tidal volume of 200 ml around a lung

volume close to their functional residual capacity.

These prerecorded signals were replayed on to the two axes of an oscilloscope and were all passed through two low-pass filters to remove tape noise (cut-off at 14 Hz, 12 dB/octave). Care was taken with the calibration of the tape recorder to ensure that the replayed signal levels were as close as possible to the prerecorded levels. One of the five occasions for each of the 12 subjects was selected at random for replaying. The 10 successive values of R_{aw} and V_{tg} were assessed by aligning a rotatable cursor parallel with the traces displayed on the oscilloscope screen and reading the slope of the trace from a circular scale. R_{aw} was assessed between flows of 0 to 0.4 litres sec^{-1} in the inspiratory direction. From these slopes R_{aw} , SR_{aw} (specific resistance), and V_{tg} were calculated. All the estimates for a given subject were made successively by all the observers, whose order in assessing the readings was randomised so as to minimise the effects of any drift which might have occurred in the replayed signal levels (no drift was noticed).

The five observers were all members of the staff of the Environmental Hazards Unit. Observer AB was considered very experienced in this technique, having made thousands of measurements over 12 years. Observers PL and CB were very familiar with the technique, while observers JE and BB were less experienced and were given periods of practice before the experiment.

Results

The values of V_{tg} , R_{aw} , and SR_{aw} were examined for observer differences by analysis of variance. In all these analyses SR_{aw} behaved in the same manner as R_{aw} and so only the results for V_{tg} and R_{aw} are discussed.

Both V_{tg} and R_{aw} showed highly significant observer and subject differences ($p < 0.001$). The observer variations were systematic in that the rankings of the values obtained by the observers varied little between subjects (Fig. 1a, b); the means of the values of R_{aw} and V_{tg} obtained by BB, AB, and PL were similar.

The mean values of R_{aw} obtained by the different observers for each subject varied substantially, and the ranges of these were proportional to the overall subject means. The range, divided by the subject's overall mean, gave a measure of the observer variability independent of the level of R_{aw} ; its average value over all subjects was 37%. This variation was larger in

the female subjects (43%) than in the male (34%).

There was a significant decrease in R_{aw} between the successive 10 measurements on all subjects and over all observers. This trend (Fig. 2a) was caused by consistently high first readings in each set of 10, and when these were excluded from the analyses the trend was no longer significant. The high first readings in sets appeared to be true high values in the subjects rather than an observer error, as the same trend was found when these same sets from the tape recordings were assessed by an automatic method (Lord and Brooks, 1977) and the results analysed for reading number variations.

The measurements of V_{tg} showed less variation than R_{aw} both between observers and with reading number. The variation between the different observers' measurements was also proportional to the mean V_{tg} of a subject, and the ratio of observer range to subject mean had an average value of 12% (Fig. 1b). No difference between these ratio values in male and female subjects was noted. There was a significant increase in V_{tg} with reading number, which over all subjects amounted to 0.1 litre between the first and last readings. This trend was barely significant when the first reading was omitted from the analyses. The effect of reading number was independent of the observer, and the trend was also seen in the values of V_{tg} made by the automatic method, indicating that it was a genuine increase in volume (Fig. 2b).

Discussion

This study supports the findings in our survey work (Lawther *et al.*, in preparation) in showing significant and substantial differences in R_{aw} and V_{tg} as determined by different observers using the method of Comroe *et al.* (1959). The values of V_{tg} were more consistent than those of R_{aw} , and our results show that great caution should be exercised when comparing measurements of R_{aw} obtained by different observers from normal subjects during survey and experimental work. We have no results for patients and subjects with high airway resistance, but since the variability in R_{aw} between observers in our series was proportional to R_{aw} we see no reason to doubt that similar variation would be observed in subjects with much higher resistances than those studied here. The consistency of the differences between the observers as shown by their nearly uniform rankings for V_{tg} and R_{aw} with respect to subject and reading number indicates that they are per-

Fig. 1 Ranges of operator means for each subject: (a) for R_{aw} and (b) for V_{t0} . (See Fig. 2 for operator symbol codes.) Subjects JP, AK, AM, and MC females. Standard errors of the means are $0.009 \text{ kPa l}^{-1} \text{ s}$ (R_{aw}) and 0.071 l (V_{t0}).

ceiving and assessing the slopes in different ways. Such perceptual differences may be important in similar tasks such as compliance determination, and even in other fields such as radar tracking. A significant interaction term in our analysis of variance between subjects and operators may indicate that the characteristic loop shapes produced by different subjects affect the judgement of slopes by an operator.

The increased variability seen with increased V_{t0} may have been due to the increased absolute error in slope for given angular error in the position of the circular cursor at large angles. For V_{t0} the angles were in the range 34° to 71° , and a 1° error in alignment would give rise to errors of 0.08 l and 0.56 l in V_{t0} respectively. A similar argument does not apply to R_{aw} , for the range in angle was 12° to 33° , giving, at a fixed V_{t0} of 3 l , errors of $0.001 \text{ kPa l}^{-1} \text{ s}$ in R_{aw} at both extremes.

We cannot explain the higher consistency

of the R_{aw} determinations in the male subjects.

In this study all the observers' means for each reading number followed the same pattern as that obtained by an automatic method (Fig. 2). There was little evidence of a linear trend between successive readings of R_{aw} once the first in the sets of 10 had been excluded from the analyses, contrary to what was found in our other series (Lawther *et al.*, 1973 and in preparation; Lord and Brooks, 1977). In this present series fewer sets of signals were examined and the lack of a significant trend may be due to this.

In all our studies the first reading of R_{aw} within a set has been found to be high, and therefore it should be used with caution since it is not clear what is the significance of this anomaly.

We should like to thank our colleagues within the Air Pollution Unit for their cooperation and help with the work.

Fig. 2 Means for each operator for each of 10 successive readings: (a) for R_{aw} and (b) for V_{tg} . Standard errors are $0.008 \text{ kPa l}^{-1} \text{ s}$ (R_{aw}) and 0.061 (V_{tg}).

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