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The effect of changes in ambient temperature on the reliability of acoustic rhinometry data*

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SUMMARY

The effect of changing ambient temperature on the reliability of acoustic rhinometer data was examined. The acoustic rhinometer was set up in a climate chamber, and connected to a simple cylindrical model containing a constriction. This constriction was at 22.5 cm from the microphone. This would be the position of the tip of a 7.5-cm nose piece, relative to the microphone, when attached to the rhinometer. The ambient temperature was increased from 10°C to 40°C. The position of the constriction as recorded by the acoustic rhinometer was compared in the same stable model at intervals during the temperature increase. The point of identification of the constriction varied with ambient temperature and the change almost perfectly followed the expected changes in the readings given the relationship of the speed of sound in air to ambient temperature. A shift of approximately 1 mm along the X-axis per 2.5°C change in temperature is seen for this constriction. In a human subject the whole acoustic rhinometry trace would shift along the X-axis to the same degree when using a 7.5-cm nose piece. Volume estimates are calculated between two fixed points on the X-axis and may be profoundly affected by even a small shift of the acoustic reading along this axis. Acoustic rhinometry data should always be collected under the same stable environmental conditions.

Key words: ambient temperature, acoustic rhinometry, standardisation

INTRODUCTION

The use of the acoustic rhinometer to quantify changes in the nasal cavity is increasing (Hilberg et al., 1989, 1990; Lenders and Pirsig, 1990). Unfortunately, its use has not been standardised. The purpose of this paper is to illustrate potential for recording erroneous data, if the recordings of the same subject are not made under the same environmental conditions. The function of the acoustic rhinometer is by definition dependant on the properties of sound, and more specifically on the speed of sound in air. The instrument uses this value to construct the graphical display and calculate the distance to specific points on the acoustic trace. It can be shown that for changes of pressure at constant temperature the speed of sound c is constant, but increases with rising temperature (Wood, 1960). It is therefore likely that data produced by the acoustic rhinometer will vary with ambient temperature. The significance of this effect is examined.

METHODS

The acoustic rhinometer (GM Instruments Ltd., Kilwinning, UK) was set up in a climate chamber, and connected to the model shown in Figure 1. The position of the constriction would correspond to tip of a 7.5-cm nose piece in measurements from a human subject. The ambient temperature was gradually increased from 10°C to 40°C and data from the model was collected at intervals during the increase. The acquired data was compared to the expected changes in the readings calculated from the relationship of the speed of sound in air to ambient temperature. The microphone of the acoustic rhinometer is at the true zero used in all calculation made by the rhinometer, but for convenience only the data beyond the base of the nose piece (i.e., beyond 15 cm) is shown graphically on the monitor. The distance to a particular feature is calculated from the number of data between the microphone and a given feature and the distance between each data point. The distance x between each data point is calculated from: $x=c/2f$, where c is the speed of sound and f is the microprocessor sound-sampling frequency of the acoustic rhinometer, which was set at 50,000 Hz. The distance to a given point can thus be determined by simple addition. The default setting of the acoustic rhinometer for the speed of sound is fixed at 346 m/s, and therefore x is set at 0.346 cm. However, the actual speed of sound c at a given temperature t (in °C) is given by: $c=331.6+0.6t$ (Wood, 1960)

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and therefore, as the ambient temperature changes the magnitude of the distance between each data point will change. The acoustic rhinometer will continue to calculate the distance to a given discontinuity using its default setting. This would have the effect of placing the same discontinuity further away from the microphone in a cold room, and closer to it in a warm room. A constriction of 0.7-cm diameter was placed at 7.5 cm away from base of the model, which is 22.5 cm from the microphone. This is equal to $(22.5/x)$ data points, where x is the distance between each point. As the environmental temperature is varied the number of data points N in the 22.5-cm span would be expected to change as follows: $N=22.5/(0.001c)$. Therefore, with a decrease in temperature there would be more data points between the microphone and the constriction. In the present study the predicted movement of a constriction placed at 7.5 cm from the zero (or 22.5 cm from the microphone), was compared to how the position of the constriction was seen to change when the rhinometer was used at temperatures between 10°C and 40°C.

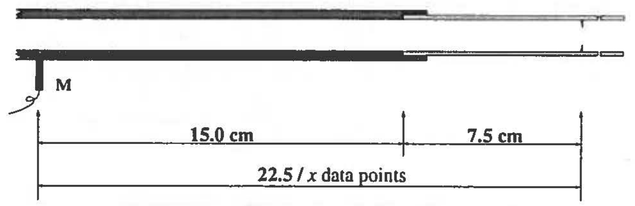

Figure 1. A schematic diagram of the proximal part of the model used to study relationship of ambient temperature to distance axis of the acoustic rhinometer is shown. The microphone (M) in this design of acoustic rhinometer is placed at 15.0 cm proximal to the zero setting of the rhinometer. This places a constriction located at 7.5 cm from zero at 22.5 cm. The number of data points that lie between the two is given by $22.5/x$, where x is the distance between each data point. This is fixed at 0.346 cm by the acoustic rhinometer and is the distance between each data point of the graphical display produced by the acoustic rhinometer.

RESULTS

It can be seen from Figure 2 that, as predicted, the point of identification of a known constriction varied with ambient temperature. The degree of change in position almost perfectly

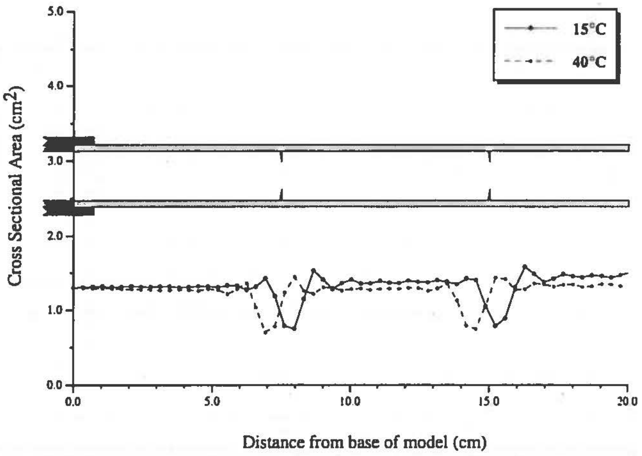

Figure 2. Acoustic trace produced by a cylinder of constant diameter of 1.3 cm interupted by a constriction of 0.7 cm at 7.5 cm and at 15 cm, at temperatures of 15°C and 40°C. At the higher temperature the constrictions appear closer to the base of the model, and at the lower temperature further away.

followed the variation in the position of the constriction predicted from the relationship of the speed of sound to air temperature. This is illustrated in Figure 3. A shift of 1 mm along the X-axis per 2.5°C change in temperature is seen for this constriction. Thus a temperature difference of 5°C between measurement would cause a shift of approximately 2 mm.

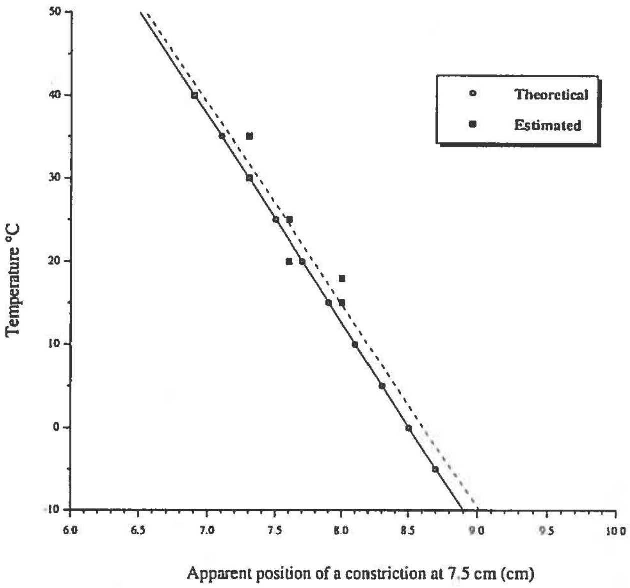

Figure 3. Comparison of the theoretical relationship of ambient temperature to the expected position of a constriction placed at 7.5 cm, to the position measured by the acoustic rhinometer over a range of environmental temperatures. The apparent position of the constriction is dependant on ambient temperature, and the degree of movement is given by the gradient of this line. The experimentally observed shift in position closely follows the theoretically determined expected shift. The rate of movement is 1 mm per 2.5°C change in temperature.

DISCUSSION

Changes in ambient temperature have been shown to significantly affect the position of a particular discontinuity along the X-axis. In this study a nose piece of 7.5 cm is represented, and it has been shown that changes in temperature will cause a shift in the data beyond this point of at least 1 mm along the X-axis for every 2.5°C change in temperature.

The temperature within the nose is relatively stable and the dimensions of that part of the acoustic rhinometry trace taken from the nasal cavity would not be expected to change to any significant degree with ambient temperature. However, the column of air between the microphone and the tip of the nose piece is at ambient temperature and the speed of conduction of sound through this air will vary. The estimated length of this region is an integral component of any distance estimation to features in the nose, as the actual zero point in any calculation is at the microphone and not the base of the nose piece, which is the position, chosen for convenience, of the zero on the graphical display. As the temperature varies the position of this arbitrary zero remains the same (15 cm) while the distance to it, as estimated by the acoustic rhinometer, changes. In warm air this distance is underestimated and the trace from the nose will shift toward the zero on the X-axis, causing features within the nose to appear more anterior than they actually are. The reverse would be true in the cold.

For small changes in temperature the shift would be negligible and also irrelevant if one were only interested in the cross sectional area at a particular feature of the trace. However, volume estimates are calculated between two fixed points on the X-axis and may be profoundly affected by even a small shift of the acoustic reading along this axis. Thus, it is possible that either imaginary changes in volume could be created or actual changes be lost with a temperature variation between readings. It is conceivable that if a subject were to be examined in the summer in a warm sunny room and then re examined following a particular surgical treatment, for example, a few months later on a cold winter morning, a significant temperature difference may exist between the two situations. The two sets of data would not be comparable.

This point brings into question the practice of measuring changes in volume from fixed points on the X-axis. It is extremely important to have in place a method for ensuring the nose piece and wave tube remain in the same position relative to internal nasal structures. A similar degree of shift of the acoustic rhinometry trace as was seen with changes in temperature could be produced by varying the degree of insertion of the nose piece. It may be more appropriate to measure volume changes between two features of the trace itself rather than using the X-axis.

The acoustic rhinometer should always be used under the same environmental conditions. Ideally, one would be expected to confirm the acoustic rhinometer is consistently estimating cross-sectional area and the position to a particular feature along the distance axis. This could easily be achieved with a simple cylindrical model containing a discontinuity at a known point. An accurate model of the human nasal cavity is not required.

Alternatively, it would be possible, with machine and software modifications, for the acoustic rhinometer to calculate its dimensions using actual ambient temperature.

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