5 Discussion

The clinical results demonstrate that the new aerial performed better than the belt aerial by reducing the time the pill was in the signal loss zone by one-third and nearly halving the number of poor signals. From the laboratory tests it is apparent that the belt aerial has a good pickup range when the radio pill's coil is parallel to the belt aerial's coil, but is severely restricted in the two other orientations. This produces frequent 'poor signals' when the pill twists and turns during its passage through the colon. These excursions into the 'signal loss zone' are more likely when a large diameter of aerial is required.

The pickup areas are greater for the new aerial, making it much less sensitive to radio pill orientation. Even when tested under conditions simulating an obese patient it was able to receive signals from a radio pill up to 100 mm beneath the aerial's surface at the three selected orientations of the pill. Although its range in the vertical plane is half that of the belt aerial, this did not appear to give problems, probably because large 'mass movements' of colonic contents are infrequent events.

The design of the new aerial could be improved by increasing the number and/or diameter of turns in the coil. This would increase the size of the 'pickup' zone, but not appreciably alter its shape, which is determined mainly by the radius to which the aerial is formed. However, with a single coil there will always be a 'null zone' where the capsule is perpendicular to the aerial.

6 Conclusion

A novel design of flexible aerial has been tested and compared with a conventional concentric coil aerial. Multidirectional characteristics and ease of application make it an attractive alternative to multi-aerial arrangements, particularly when following a radio pill as it moves through the gastrointestinal tract.

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References


Technical note

Gas mixing for biomedical application using mass flow controllers

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1 Introduction

For laboratory as well as for clinical purposes the need for gas mixtures of known and constant composition is obvious. These mixtures are among other things used for respirators, fluid tonometry, blood gas analysis and calibration purposes. To achieve the most reliable results, primary standards, prepared gravimetrically (NBS National Bureau of Standards, USA; CITI Chemical Inspection & Testing Institute, Japan; VSL Van Swieten Laboratory, The Netherlands) should be used. Availability as well as high price do limit their applicability; secondar standards are commonly used.

To meet the demands as to quantity as well as composition, most institutes prefer to prepare their own gas mixtures. To this end, gravimetric, volumetric or manometric preparation from the pure constituent gases is widely employed. In laboratory conditions, with the need for various mixtures, gas-mixing systems using gas-mixing pumps (Wösthoff Bochum, FRG) are most often used. This system provides constant mixtures of accurately known composition but at a fixed rate of flow, and the variation in the mixtures which can be obtained is limited by the number of driving wheels. Mixing of gases on that basis of the control of flow offers the advantage of versatility.

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A system based on the principle of variable valve opening times under microprocessor control has been described (Shrewsbury, 1979). However, this system is inaccurate in the low flow range and shows intercomponent variations.

A gas-mixing system containing mass flow controllers (MFCs) is more versatile and accurate for biological applications (Frankvort, 1982). Such a system offers the advantage of high precision and wide flow ranges, while the concentrations in the produced mixtures are independent of the flow rate. The disadvantages are the time-consuming calculation of concentration from flow data and the need for calibration.

For the measurement of the influence of CO₂ on the interaction of oxygen and haemoglobin in human blood (Kwant et al., 1988) we developed an arrangement containing four MFCs (Bronkhorst High-Tech, Ruurlo, The Netherlands) to make gas mixtures for the equilibration of blood samples. The desired gases are mixtures of O₂, CO₂ and N₂. The concentration of O₂ must be varied between 0 and 90 per cent, the concentration of CO₂ between 0 and 20 per cent, while N₂ is used for balance. The chosen concentration of CO₂ must be kept constant while the O₂ concentration is varied between 0 and 90 per cent. This has been attained by combining two pairs of MFCs, one pair for mixing CO₂ in O₂ and the other pair for mixing CO₂ in N₂. In this way two ‘primary’ mixtures are made with equal CO₂ concentrations. By varying the ratio between these ‘primary’ mixtures a final mixture is made in which the O₂ concentration can run from 0-000 to 90 per cent while the CO₂ concentration remains constant.

2 Materials and methods

Principles of MFC operation are well known (Noltink, 1988). The MFC unit is provided with a control box from which an output voltage \( U_q \), proportional to the flow, can be obtained. The desired flow can be adjusted by applying a set point voltage \( U_s \) to the control box. For the automated calibration procedure these signals are connected to a computer system (Minc, PDP-11/23, Digital Maynard, Massachusetts, USA). Calibration of flow is attained by measuring the flow through each MFC with a soap bubble meter at the setting of 0, 25 per cent, 50 per cent, 75 per cent and 100 per cent of maximum flow. The mixing performance of each pair of MFCs is calibrated and checked for reproducibility by mixing O₂ flowing through the small MFC1 (0–150 ml min⁻¹) with N₂ flowing through the large MFC2 (0–1000 ml min⁻¹) while comparing the flow signals of the MFCs \( (U_q) \) as well as the resulting composition of the mixture with the setpoint voltage \( (U_s) \).

The setup for calibration is shown in Fig. 1. Oxygen concentration in the mixture is measured using a Beckman OM-11 oxygen analyser. Calibration of the OM-11 is performed using N₂ and dry air. The whole procedure is performed automatically using the computer-controlled data-acquisition system. Digital-to-analogue conversion is used to feed the setpoint values \( U_s \) to the MFCs and to control the valves for calibration of the OM-11. Analogue-to-digital conversion is used to measure flow signals \( U_q \) from the MFCs and oxygen concentration from the OM-11. The calibration procedure as incorporated in the software is outlined in the following steps:

0 start of calibration procedure
1 zero calibration of OM-11 for 5 min. Read O₂ signal
2 air calibration of OM-11 for 5 min. Read O₂ signal
3 Set MFC2 (0–1000 ml N₂) to desired value
4 set MFC1 (0–150 ml O₂) to desired value
5 read MFCs. Acceptance level 0.0015 mV (=0.003 per cent fullscale). If not then step 3
6 read O₂ signal every 30 s until AO₂ of three sequential readings <0.005 kPa
7 read MFCs. Acceptance level 0.0015 mV. If not then step 3
8 air calibration of OM-11. Acceptance level 0.01 kPa. If not then step 3
9 store MFC and O₂ readings
10 if next MFC1 setting then back to step 3 else step 11
11 zero calibration of OM-11. Acceptance level 0.005 kPa. If not then step 3
12 store MFC and O₂ readings
13 if next MFC2 setting then back to step 3 else step 14
14 end of calibration
15 calculate, print and plot results.

The various acceptance levels refer to predetermined differences between theoretical values and practical readings. The number as well as the magnitude of the steps for setting the MFCs can be chosen by the operator. We mostly used four steps for MFC2 (250, 500, 750 and 1000 ml) and ten steps of 15 ml for MFC1. The whole procedure can be performed overnight and so does not interrupt the daily availability of the system.

3 Results and discussion

The calibration procedure results in equations from which for each setting of MFC2 the setting of MFC1 to obtain a certain mixture can be calculated. The equations are given in such a form that the desired mixing proportion \( X \) of the gas supplied by MFC1 to the mixture results in a value for dialling the digital read-out of the control box.

To show the precision of the mixing system, five different MFC settings were calculated to obtain oxygen concentrations ranging from 2 to 20 per cent. The resulting mixtures were measured by the OM-11. This experiment was carried out on 18 different days in the course of one year. The results are shown in Table 1. One has to consider that the results contain imprecision of the mixing system as well as imprecision of the oxygen analyser.