Chapter 5

VARIABILITY OF PCO₂ BREATH-BY-BREATH IN NORMAL MAN

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1. INTRODUCTION

Ventilation is finely adjusted in relation to the metabolic needs of the body, with alveolar (and arterial) gas pressures maintained steady at rest and in submaximal exercise. Constancy of the mean alveolar PCO₂ has been known for at least 80 years.¹

When the rate of CO₂ arrival at the lung from mixed venous blood varies breath-by-breath alveolar PCO₂ will also vary if breath-by-breath ventilation does not change in proportion. Where alveolar PCO₂ is steady the CO₂ flux into the alveolar compartment will equal the rate of appearance of CO₂ at the mouth (VCO₂). Alveolar PCO₂ is well represented at rest by end-tidal PCO₂ (PetCO₂).

It has been noted recently that, even after half an hour’s quiet rest, designed to achieve a steady state, breath-by-breath ventilation varies considerably, despite relative constancy of end-tidal PCO₂ (PetCO₂).² The present study was designed to measure breath-by-breath variability of inspiratory ventilation (VI), CO₂ delivery to the atmosphere (VCO₂) and PetCO₂ and to see whether VI and VCO₂ were correlated.

2. METHODS

2.1. First series – Procedure

Nine normal subjects (4 male; 5 female) were familiarised with the laboratory prior to the investigation.² On the day of the experiment the subject reclined on a couch soon after arrival and a facemask was applied for 5 minutes. After 3 minutes airway flow and PCO₂ were recorded for approximately 2 minutes (approximately 30 breaths). The facemask was then removed. This was a non-steady state familiarising procedure. The
subject remained resting on the couch for 30 minutes before the mask was re-applied for 5 minutes. Steady-state respiration was recorded following a 3-minute wait.

2.2. Equipment and Calibration – 1st series

Airway flow was recorded from a pneumotachograph attached to a facemask (Validyne MP45 pressure transducer, P.K. Morgan, Chatham, Kent, UK). Airway CO₂ was sampled from the mask inlet (Morgan Capnograph, Model 455). Flow and CO₂ signals were digitised (3D Digital Design and Development Ltd., Chelmsford, Essex, UK) and displayed for later computer adjustment of the delay between flow and CO₂ signals (Codas system, Dataq Instruments Inc., Software Release Level 3, Ohio, USA). The signals were sampled via a second analogue-to-digital converter at 10-ms intervals (Systematika Ltd., London, UK) and analysed in real time.³

On line values were obtained for inspiratory ventilation (VI), end-tidal CO₂ tension (PetCO₂) and CO₂ production rate at the mouth (VCO₂). Calibration for CO₂ utilized a 5% CO₂ gas mixture, and tidal volume a standard 1 L syringe.

2.3. Second series – Procedure

There were five normal subjects (4 male, one female) in this study who were already familiar with the laboratory. Each subject rested for a few minutes seated on a cycle ergometer (Maarn Fitness Equipment, The Netherlands) before starting a 2-minute record of resting breathing (airway CO₂ and tidal volume). After 3 minutes exercise at 50 watts a further 2 minutes recording was made.

2.4. Equipment and Calibration – 2nd series

The subject breathed through the stem of a three-way valve (P.K. Morgan). Inspiratory volume was measured with a turbine (Micro Medical, micro-flow head from a George Washington coupler unit, FC112). The signal was processed by a Harvard Coupler unit (Model A100, Edenbridge, Kent). Airway CO₂ was measured using a Morgan capnograph. Recording utilised the CED (Cambridge Electronic Design, Model 1401, Cambridge, UK) analogue-to-digital converter and Spike2 software (CED). A 5% CO₂ gas mixture and 1 L syringe were used for calibration.

3. RESULTS

3.1. Study 1. Inspiratory ventilation, VCO₂ and end-tidal PCO₂ at rest (9 subjects)

Results for study 1 appear in table 1.

Figure 1 shows PCO₂, VCO₂ and VI values from subject 1. On the left PCO₂ and scaled VCO₂ and VI values are plotted against time. A smoothed curve is fitted through individual breath values for each variable. On the right VI is plotted against VCO₂ for all breaths.