Diagnosing and quantifying incomplete expiration in patients with lung disease

Editor—Incomplete expiration is common in smokers and patients with chronic obstructive pulmonary disease (COPD). This can increase FRC and auto-PEEP. The increased intrathoracic pressure may compromise venous return or, if great, could cause a pneumothorax. We report a simple new method for detecting this, which appears quick and reliable, and can quantify the increase in lung volume.

During mechanical ventilation of an anaesthetized subject, we set the APL valve to zero and then discontinued ventilation for approximately 10 s, allowing complete expiration to occur. Complete expiration was verified by confirming that the expiratory flow rate shown on the flow—volume loop was zero. The ventilator was restarted using the previously set rate and volume and the flow—volume loop was observed (Fig. 1). With the GE s/5 spirometer (D-lite), which displays successive individual inspired and expired volumes, the differences between inspired and expired tidal volumes were added for the next three respiratory cycles. We have called this the volume of incomplete expiration, since it represents the volume retained by the respiratory system when the previous pattern of mechanical ventilation is resumed.

A female aged 71 yr with a history of 40 pack years of smoking and symptoms and signs of severe COPD underwent a total abdominal hysterectomy. The volume of incomplete expiration was 380 ml. This feature was reproducible, with other measures of incomplete expiration, resulting in volumes of 310, 400, and 290 ml (mean 345 ml) during the anaesthetic (Fig. 2).

A further patient with a long history of smoking, although no formal diagnosis of COPD showed incomplete expiration with a mean total volume of incomplete expiration of 215 ml (200–250 ml) over four trials.

As a control patient, a man of 62 yr with no respiratory disease and a non-smoker undergoing a hemi-colectomy had a mean volume of incomplete respiration of 10 ml (−50 to 50 ml) over four trials.

Similarly a man of 65 yr also a non-smoker with no respiratory disease undergoing an open right radical nephrectomy had a mean volume difference of 40 ml (10–100 ml) over four trials.

This technique was used in various patients and seems to be useful in both confirming and quantifying incomplete expiration. There appears to be a difference between observed values of our four patients, which correlates with the severity of clinically observed airways disease.

We cannot find previous reports of this manoeuvre, of discontinuing ventilation and measuring subsequent volume changes when mechanical ventilation is recommenced. This could be particularly useful as most other methods of detecting incomplete expiration rely on pressure measurement, as opposed to volume, and do not quantify the degree of incomplete expiration.

Detecting incomplete expiration is clinically useful. Various strategies can reduce incomplete expiration, such as reducing the I:E ratio or the tidal volume. Perhaps, the

![Fig 1](image1)

**Fig 1** Flow–time plot from GE s/5 monitor, with volume measurements from d-lite spirometer module. There are three breaths on this screen. Breath 1 is the equilibrium condition as both inspiratory and expiratory tidal volumes are 450 ml. Ventilation was discontinued after breath 2. The flow rate is zero for a sustained period ensuring complete expiration. When ventilation was recommenced, with breath 3, the expiratory tidal volume decreased to 390 ml, despite an inspiratory volume of 450 ml. Thus, this patient had incomplete expiration of 60 ml. Plotting breaths 1 and 3 together, one can see the horizontal distance, which indicates expired volume, is noticeably smaller. Although the increase in expired volume on prolonged exhalation (breath 2) was evidence of incomplete expiration, this appeared inconsistent and unreliable.

![Fig 2](image2)

**Fig 2** Flow–volume loop from case 1. After a prolonged expiration, ventilation was recommenced and a flow–volume loop created. The expiratory flow is zero before volume returns to the starting point of the loop, indicating that the expired volume is less than the inspired volume.
The most useful aspect of detecting incomplete expiration is simply to alert the clinician to the severity of underlying lung disease, which could influence further management of the patient.

In conclusion, using a clinically available spirometry system, we describe how to detect incomplete expiration in anaesthetized mechanically ventilated patients in a simple, reliable, and quantifiable way. Equipment to do this is commonly available in theatres and in ICUs in the UK. Further studies are needed to validate the method.

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A foam-cushion face mask and a see-through operation table: a new set-up for face protection and increased safety in prone position

Editor—Positioning the head of patients undergoing procedures in prone position is crucial and remains a difficult task for the anaesthesiologist. Often, it is a compromise between a normal position of the head without derogating facial and neck tissues on the one hand and sufficient control over airway devices on the other hand. Most reported sequelae associated with prone positioning are due to unnoticed pressure on the head and neck region and range from mild irritation to disastrous complications, such as corneal abrasion, central retinal artery occlusion leading to impaired vision, or even stroke due to neck torsion-induced vertebral artery occlusion. We believe that the main problem in head positioning is based on the fact that we, as anaesthetists, try to fit the patient’s face into the available support cushions and not the cushion onto the patient’s face, which would allow complete control over head position. Therefore, we developed a technique using a commercially available foam-based boxing helmet that is fitted to the patient before turning to the prone position and guarantees that the face and eyes are free from pressure (Fig. 1). The helmet also keeps the neck in a straight line without forcing it into tilting or turning positions, thus avoiding compression or torsion of vessels and nerves, although all airway devices remain accessible and safe. To be able to control pressure on soft tissue structures and to supervise airway devices, we use an operating table with a clear plastic window in the head and neck region. A mirror mounted underneath allows the anaesthetist to see the position of face and airway devices at all times (Fig. 2). We believe that the combination of a face mask and positioning on the see-through table may be a sensible and cost-effective yet simple approach to reduce positioning-associated side-effects and increase safety during prone position procedures.

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3 Jackson L, Keats AS. Mechanism of brachial plexus palsy following anesthesia. Anesthesiology 1965; 26: 190–4