Intensive Care Med (1997) 23: 704–707

TECHNIQUE

A. K. McIndoe
P. Stewart
I. H. Wilson

Drawover vaporizers for sedation in intensive care

Received: 7 November 1996
Accepted: 6 March 1997

A. K. McIndoe (✉)[1] · P. Stewart · I. H. Wilson
Department of Anaesthesia & Intensive Care, Royal Devon & Exeter Hospital (Wonford), Barrack Rd, Exeter, EX2 5DW, U. K.

Present address:
[1] Sir Humphry Davy Department of Anaesthetics, Bristol Royal Infirmary, Marlborough Street, Bristol BS2 8HW, UK
Fax: +44 (1392) 402 472
e-mail: 100756.3126@compuserve.com

Abstract *Objective:* We have undertaken a laboratory study to determine whether a drawover vaporizer in the inspiratory limb of an intensive care ventilator circuit can produce safe and therapeutic concentrations of isoflurane.
Design: An Oxford Miniature Vaporizer (OMV) and Ohmeda TEC vaporizer were assessed over the range of inspired isoflurane concentrations, airway pressures and tidal volumes experienced in the ICU.
Conclusions: The experimental findings suggest that the OMV inhaler in plenum mode can be relied upon to produce safe concentrations of isoflurane over a clinically useful range of inspired concentrations. Furthermore, it behaves predictably over the range of airway pressures likely to be encountered in the patient admitted with acute severe asthma. However, we found that the Ohmeda TEC vaporizer did not perform reliably in this setting.

Key words Equipment · Vaporizer · Intensive care sedation · Drawover anaesthesia

Introduction

Inhalational anaesthetic agents have been intermittently used as a means of providing sedation for patients requiring mechanical ventilation on the Intensive Care Unit (ICU) and for the management of severe, refractory bronchospasm [1, 2, 3]. Low solubility agents, such as isoflurane, can provide a controllable level of sedation and, since elimination is independent of renal and hepatic function, patient response can be predicted on the basis of inspired concentration and minute ventilation [2, 3]. Minimal metabolism of the sedative agent (0.2 % for isoflurane) means that nephrotoxicity and hepatotoxicity are unlikely to occur.

Administration in the ICU setting is generally difficult to organize, requiring the use of theatre anaesthetic machines or specialized vaporizers in an area not equipped to scavenge expired anaesthetic gases. Some ventilators require specific vaporizers to provide adequate and controlled vapour concentrations in the patient circuit. The Ohmeda TEC (Ohmeda, UK) and Oxford Miniature Vaporizers (OMV) (Penlon Ltd, UK) have been used extensively in drawover mode to produce anaesthesia in situations where pressurized gas supplies are not freely available. It has been shown that the OMV can reliably maintain anaesthetic concentrations when used in circuit in "pushover" or plenum mode [4].

We decided to investigate in a laboratory study whether a drawover vaporizer in the inspiratory limb of the ventilator circuit could produce safe and therapeutic concentrations of isoflurane in the clinical ICU setting.

Materials and methods

A series of experiments were carried out to evaluate the performance of each vaporizer over the range of inspired isoflurane concentrations, airway pressures and tidal volumes experienced in the ICU. Both vaporizers were assessed within the inspiratory limb of a patient circuit connected to a Servo 300 Intensive Care ventilator (Siemens, Scandinavia) (Fig. 1). Patient variables were simulated with the use of a Pulmo-sim artificial lung (Blease, UK). Both vaporizers had been set up according to the manufacturers' specifications at room temperature prior to each set of observations. Inspired concentrations were set using the calibrated scale on each

vaporizer. We elected to study the performance of the two vaporizers with tidal volumes of 300, 500, and 700 ml and changed the resistance of the artificial lung so that both vaporizers were assessed at 20, 40, and 60 cmH_2O inflation pressure.

Variations in tidal volume were achieved by changing the set tidal volume on the Servo ventilator until the desired delivered volume had been registered by the ventilator. Simulated changes to airway plateau pressure were achieved by increasing the resistance of the artificial lung. Pressure was measured in the proximal portion of the inspiratory limb of the ventilator circuit by an aneroid gauge on the artificial lung and was found to agree consistently with that displayed on the Servo 300 ventilator. Inspired concentrations of isoflurane were monitored to two decimal places at the patient mouthpiece by means of a Capnomac ultima (Datex, UK), which had been calibrated, according to the manufacturer's specification, with a standard gas cylinder mixture (carbon dioxide 5.0%, oxygen 55.0%, nitrous oxide 36.0%, enflurane 3.0%). We assessed the vaporizer output at inspired settings of 0.5%, 1%, and 2% isoflurane. Delivered concentration was measured when the monitored 'breath by breath' trace of the anaesthetic agent stabilized and was directly superimposed on the previous screen trace (typically less than 60 s after commencing flow). The vaporizer was allowed to equilibrate with room temperature between measurements and two data sets were collected for each setting. There was no significant difference between the two sets of measurements.

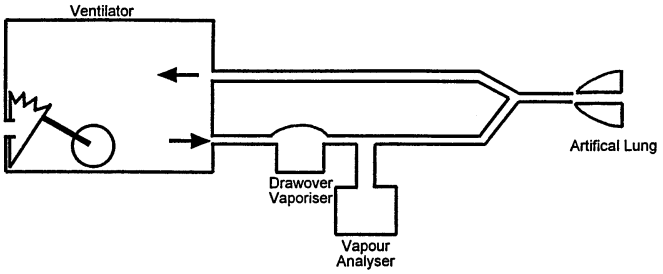

Fig. 1 The vaporizer was sited in the inspiratory limb of the ventilator circuit. Delivered vapour concentration was measured in the distal portion of the inspiratory limb

Results

The results were plotted for both vaporizers on a series of three graphs (Fig. 2). In each instance the effect of increasing inspiratory pressure was plotted against delivered concentration at the three different vaporizer settings. Each graph demonstrates the results obtained at a different set tidal volume.

The OMV remained unaffected by increases in circuit pressure but demonstrated a tendency to overdeliver at the 2% setting in the presence of low tidal volumes. None of the recorded inspired concentrations were greater than 30% in error of the set concentration. At all tidal volumes, inspiratory pressures and concentration settings the OMV behaved in a predictable, stable fashion.

The Ohmeda TEC vaporizer delivered a predictable concentration only at an airway pressure of 20 cmH_2O. Increasing airway pressures gave rise to an increased delivered concentration, in excess of the set level. This variation in performance was most marked at low set concentrations of isoflurane such that an airway pressure of 60 cmH_2O produced an error greater than 200% over the set concentration of 0.5%.

Discussion

Volatile agents have been used to produce sedation in ICU and are also used as a treatment for bronchospasm [1, 2, 3]. Isoflurane, for example, has been used successfully in children for the management of status asthmaticus in inspired concentrations of up to 1.5% [1]. The major disincentives to using volatile agents in ICU are related to the difficulties of administration without the use of an anaesthetic machine and the problems of exhaled gas scavenging outside the theatre environment. A convenient form of scavenging for most units is the Cardiff Aldasorb (Shirley Aldred & Co. Ltd, UK) which is small enough to be attached to the expiratory port of the ventilator [2]. At the inspired concentrations of 0.1–0.6% isoflurane required to give optimal sedation these devices need to be changed once every 24 h [2].

The Oxford Miniature Vaporizer was designed in 1962 as a means of delivering limited amounts and concentration of inhaled anaesthetic agents via a portable and lightweight piece of equipment [4]. It has interchangeable scales allowing it to be used to administer isoflurane, enflurane or halothane. The vaporizer is thermally buffered rather than thermocompensated so that the output tends to reduce as ambient or vaporizer temperature falls [5]. Changes in internal temperature as a result of the heat lost during vaporization are buffered by the presence of a water/ethylene glycol jacket and by the internal design of the vaporization chamber. Differences in the calibre of holes in the down tube to the vapour chamber result in passive alteration of the splitting ratio in response to changes in the vapour density. As the vapour temperature falls during use, vapour concentration and vapour density fall, causing an increased diversion of gas via the longer route through the vaporization chamber. This change in splitting ratio provides a degree of temperature compensation such that output is not directly proportional to changes in saturated vapour pressure. Previous laboratory and clinical assessment have confirmed that in both drawover and plenum mode, the vaporizer output does not appreciably exceed the set concentration [4, 5, 6]. Ambient environmental temperature changes can feasibly alter vaporizer output [7, 8] but in the temperature-controlled ITU environment, air conditioning will render this effect less significant than changes in internal temperature occurring as a result of vaporization of the isoflurane.

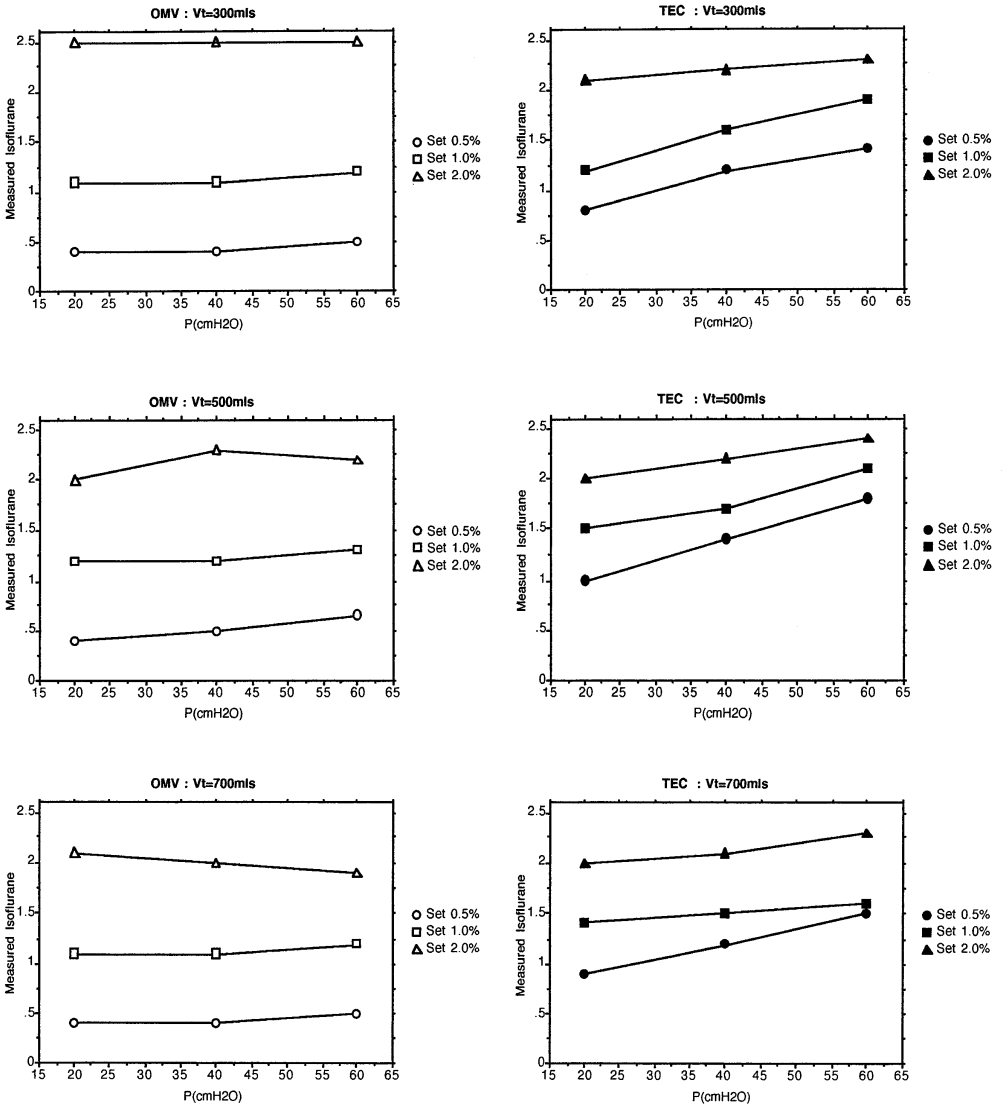

Fig. 2 Plots of delivered concentration of isoflurane at airway pressures of 20, 40, and 60 cmH_2O. At each pressure, measurements were made using tidal volumes of 300, 500, or 700 ml and at three different set concentrations (0.5 %, 1 %, and 2 % isoflurane). The graphs on the left represent results obtained using the OMV, those on the right correspond to the Ohmeda TEC vaporizer

The Ohmeda TEC vaporizer is temperature-compensated by a bimetallic strip that alters the splitting ratio in response to changes in temperature within the vapour chamber or the ambient surroundings. As a result, the vaporizer output is largely independent of both internal and external temperature. The fluctuations and errors in output at low flows and high airway pressures are difficult to explain. Ward describes various anomalies which may be attributed to the effects of back pressure and transient backflow in a vaporizer [9]. In itself, back pressure may cause the oscillatory flow of a carrier gas in a vaporizer chamber, increasing vapour saturation. Back pressure that leads to the local reversal of flow may feasibly cause saturated vapour to be forced back through the bypass, increasing the delivered concentration. These potential problems exist in all draw-over vaporizers because resistance to gas flow is necessarily low, however the presence of a uni-directional valve should limit their effects.

The experimental findings of this laboratory study suggest that the OMV inhaler can, in practice, be placed in plenum mode as a vaporizer in an intensive care ventilator circuit. It can be relied upon to produce safe concentrations of isoflurane over a clinically useful range of inspired concentrations, from that required to produce sedation to facilitate mechanical ventilation to those required to produce anaesthesia for short procedures such as percutaneous tracheostomy. Furthermore, it behaves predictably over the range of airway pressures likely to be encountered in the patient admitted with acute severe asthma. Underdelivery resulting from vaporizer cooling at high minute volumes may require titration of the set concentration to the clinical effect. The use of inspired concentration monitoring may be helpful, but in

the presence of a prolonged expiratory phase in asthma end-tidal measurements may not be reliable. Since previous work has demonstrated that neither end-tidal nor blood isoflurane concentrations correlate with the degree of sedation in intensive care patients, more emphasis should be placed on the clinical assessment of the patient [2]. In conclusion, use of the Oxford Miniature Vaporizer with isoflurane represents a safe, simple and readily available means of delivering volatile agents to the mechanically ventilated patient.

Acknowledgements The authors would like to thank Ohmeda for providing one of the vaporizers used in this trial.

References

1. Revell S, Greenhalgh D, Absalom SR, Soni N (1988) Isoflurane in the treatment of asthma. Anaesthesia 43: 477–479
2. Spencer EM, Willatts SM (1992) Isoflurane for prolonged sedation in the intensive care unit; efficacy and safety. Intensive Care Med 18: 415–421
3. Kong KL, Willatts SM, Prys-Roberts C (1989) Isoflurane compared with midazolam for sedation in the intensive care unit. BMJ 289: 1277–1280
4. Parkhouse J (1966) Clinical performance of the OMV inhaler. Anaesthesia 21: 498–503
5. Houghton IT (1981) The Triservice anaesthetic apparatus. Anaesthesia 36: 1094–1108
6. Schaefer HG, Farman JV (1984) Anaesthetic vapour concentrations in the EMO system. Anaesthesia 39: 171–180
7. Craig GR, Berry CB, Yeats MJ (1995) An evaluation of the Universal PAC and Oxford Miniature Vaporizers for paediatric field anaesthesia. Anaesthesia 50: 789–793
8. Wilson IH, Page RJE, Yeats MJH (1988) The Oxford Miniature Vaporizer in paediatric anaesthesia. An experimental study. Anaesthesia 43: 700–702
9. Davey A, Moyle JTB, Ward CS (1992) Ward's Anaesthetic Equipment (3rd Edn) Saunders, London