Correspondence

Sudden upper airway obstruction due to invisible rain-out in the heat and moisture exchange filter

Editor—Morgan-Hughes and colleagues[1] studied the airflow resistance of three heat and moisture exchanging (HME) filter designs under wet conditions. We report a case demonstrating that their recommendations for the safety of patients are very apposite.

A 58-yr-old male with carcinoma of the colon and metastases in the liver, and abdominal and thoracic chest wall (after unsuccessful laser therapy) was scheduled for a complex surgical procedure including right hemi-hepatectomy, and resection of the chest and abdominal wall, parts of the right hemidiaphragm, and the right lower lobe of the lung. After induction of anaesthesia, a 41 French gauge left-sided Robertshaw double-lumen tube (DLT) (Broncho-cath® endobronchial tube with CPAP System, left, 41 French, 95885, Mallinckrodt Laboratories, Ireland) was placed, and the correct position was verified by fibreoptic bronchoscopy directly, and after each repositioning.[2] Anaesthesia was maintained with oxygen 40% in an air flow of 4 litres min^{-1}, isoflurane 1–1.2 MAC, sufentanil 50 μg h^{-1} and pancuronium 2 mg h^{-1} intravenously. An HME (Gibeck Humid® Filter 19042 by Hudson RIC AB, Sweden) was placed between the ventilatory circuit (a coaxial Bain-type breathing circuit, Mallinckrodt DAR®, Italy, Breathing circuit duo REF 285/25557) and the DLT, and positioned above the patient's head to avoid mucus depositions on the filter membranes. A carbon dioxide absorber was used in a circle system. The anaesthetic machine used was an AS3® (Datex-Ohmeda Instrumentarium Corp., Finland), which provides extensive respiratory gas monitoring, as well as routine anaesthetic monitoring (electrocardiography, pulse oximetry, invasive blood pressure, central venous pressure and temperature). Respiratory rate, tidal volumes, fractional inspiratory oxygen and end-expiratory pressure are given in Table 1. During one-lung ventilation (OLV), maintenance of oxygenation was achieved by application of CPAP to the lung. No problems with ventilating the patient occurred during the first 8 h of surgery, including the first hour after initiating OLV. The inspiratory and expiratory flow curves did not raise any suspicion of water or other secretions in the ventilatory circuit.

Then a sudden increase in peak inspiratory pressure from 29 to 54 cm H_2O, combined with a decrease in tidal volume from 575 to 250 ml, occurred. Resection of the right lower lobe had been completed 5 min earlier. There had been no recent repositioning of the patient. There was no suggestion of bronchospasm or oedema of the lung. First, the correct position of the DLT was checked by fibreoptic bronchoscopy.[2] No blood or any other secretions were noted in the bronchial system. The ventilator, breathing system, and inspiratory and expiratory valves were inspected carefully, and checked for obstruction. Ventilation was then changed to two-lung ventilation (TLV), without any improvement. Left- and right-sided OLV respectively, did not reveal any difference between the two lungs. Manual ventilation was difficult. Due to the high resistance, a maximum tidal volume of only 200 ml could be administered. The surgeons opened the left pleura in order to rule out a pneumothorax. They checked for pericardial tamponade and damage to the heart and mediastinum. No pathology could be detected. Just before changing the anaesthetic machine, the original HME filter was exchanged. Thereafter, ventilating the patient was not a problem. The used HME filter had a weight of 44 g; an unused filter weighs 32 g. Outwardly the filter appeared normal, and only condensed water was visible.

Most manufacturers of HME filters warn users of the possibility of accumulation of excess condensation or patients' secretions within them. This may increase the work of breathing and cause blockage of the device. Retention of blood-stained or proteinaceous fluid in the HME filter will easily be detected,[3] but clear secretions might not be. The Humid-Vent® filter compact we used consists of plastic transparent housing, a cellulose heat and moisture retaining element, and a polypropylene filter. The technical characteristics of this HME filter are: weight, 32 g; dead space, 35 ml; moisture output, 31 mg H_2O $(litre\ air)^{-1}$ (tidal volume, 600 ml); and maximum resistance to flow, 2.4 cm H_2O at 60 litres min^{-1}.

In our patient, the routine protocol for emergency management of the breathing system obstruction failed to identify the site of occlusion. The HME filter was only taken into consideration as the source of the obstruction after all other causes had been ruled out.

Subsequently, we reproduced the scenario with a similar HME filter, under the same ventilatory settings, by adding 1 ml of normal saline incrementally into the patient's side of the filter, and connecting it to a test lung. After instillation of 10 ml, all of which was absorbed by the filter, a sudden increase in airway pressure occurred.

In our patient it remains speculative as to where the water came from. Despite a fresh gas flow of 4 litres min^{-1}, the inspired gas was highly saturated with water due to the use of a carbon dioxide absorber. This might be the reason for the formation and absorption of invisible excess water within the filter. This is, to our knowledge, the first report of sudden HME filter obstruction in the absence of proteinaceous secretions.[3] But this observation is

Table 1 At 0 min, a sudden increase in airway pressure occurred. OLV, one-lung ventilation; TLV, two-lung ventilation

	Time (OLV) (min)		Time (TLV) (min)
	–25	0	+60
Fractional inspiratory oxygen	0.4	1.0	0.4
pH	7.36	7.26	7.35
P_{CO_2} (kPa)	5.6	7.1	5.2
P_{O_2} (kPa)	20.9	43.1	27.2
Base excess (mmol $litre^{-1}$)	–1.4	–3.3	–3.9
Oxygen saturation (%)	99.1	99.7	99.3
Tidal volume (ml)	550	250	650
Respiratory rate (min^{-1})	15	18	14
Positive end-expiratory pressure (cm H_2O)	5	5	5
Peak inspiratory pressure (cm H_2O)	29	54	17
Inspiratory/expiratory ratio	1:1	1:1	1:1

consistent with the results drawn by Morgan-Hughes and colleagues,[1] who presumed that a 'tampon' effect could occur in this type of HME filter without obvious accumulation of saline or other clear secretions.

W. Schummer
C. Schummer
J. Fuchs
R. Voigt
Jena, Germany

Editor—Thank you for the opportunity of responding to the letter by Schummer and colleagues, who describe a critical incident caused by an obstructed HME filter. The device in question features a heat and moisture exchanging element and a filter contained within a largely transparent housing. The former is composed of a wound spiral of paper impregnated with calcium chloride as a hydroscopic additive. The latter is made of electrostatically charged hydrophobic polypropylene.

We have studied the performance of this device under wet conditions. Our study protocol was as previously described[1] except that cylinder air was used to generate airflow. We found a mean patient-sided dead space of 23.8 (SD 1.3) ml, a retention volume of 10 (0) ml, and a concealment volume of 6 (2.2) ml. On inspiratory airflow resistance testing, the pressure drop across the device when dry was 2.3 (0.2) cm H_2O at 60 litres min^{-1}, rising to 6.8 (0.8) cm H_2O with a 5 ml saline challenge. The addition of further increments of saline simply resulted in ejection of saline from the patient side of the device. On expiratory airflow resistance testing, the mean pressure drop across the device when dry was 2.4 (0.2) cm H_2O at 60 litres min^{-1} rising to 7.4 (2.5) cm H_2O with a 5 ml saline challenge. The addition of further increments of saline resulted in saline penetration of the filter element and was not associated with further major rises in airflow resistance.

The device is a compact design and therefore a given volume of secretions would be expected to produce a proportionally greater effect on airflow resistance compared to a larger similar device. Also, a 5 ml saline challenge produced a greater rise in bi-directional airflow resistance than any of the devices tested in our study.[1] However, the paper heat and moisture exchanger in this device did not appear to absorb saline as evidenced by a concealment volume of only 25% of the patient-sided dead space. Rather, the saline that was retained by the device seemed to be held within the paper spiral by hydrostatic forces. In addition, challenge volumes in excess of 5 ml resulted in either saline ejection or filter penetration, limiting further rises in airflow resistance. Filter penetration would afford some protection against excessive rises in expiratory pressure but has implications for the potential of infected liquid material to pass through the device.

On this basis, we feel that excessive condensation could cause a moderate increase in airflow resistance across this device but alone might not account for Schummer and colleagues' observations. We wonder about the possibility of the occult accumulation of patient secretions given the severe nature of the critical incident described.

N. J. Morgan-Hughes
D. Turnbull
G. H. Mills
Sheffield, UK

1 Morgan-Hughes NJ, Mills GH, Northwood D. Air flow resistance of three heat and moisture exchanging filter designs under wet conditions: implications for patient safety. *Br J Anaesth* 2001; **87**: 289–91

2 Klein U, Karzai W, Bloos F, *et al.* Role of fiberoptic bronchoscopy in conjunction with the use of double-lumen tubes for thoracic anesthesia: a prospective study. *Anesthesiology* 1998; **88**: 346–50

3 Williams DJ, Stacey MR. Rapid and complete occlusion of a heat and moisture exchange filter by pulmonary edema (clinical report). *Can J Anaesth* 2002; **49**: 126–31