Performance Of The Anesthetic Conserving Device In A Bench Study - The Spill Over Effect

Klinik für Anaesthesiologie St. Josef-Hospital

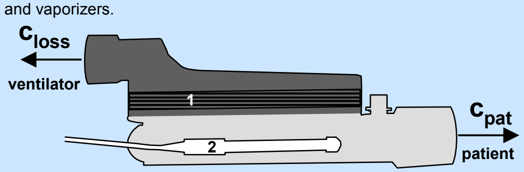
Martin Bellgardt, M.D.[1], Clemens Sirtl, M.D.[1], Javier Belda, Ph.D.[2], Heinz Laubenthal, Ph.D.[1] and Andreas Meiser, M.D.[1]

1. Klinik für Anaesthesiologie, St. Josef-Hospital, Ruhr-Universität Bochum, Germany
Gudrunstrasse 56, D-44791 Bochum; Email: martin.bellgardt@rub.de
2. Servicio de Anestesiología y Reanimacíon, Hospital Clínico Universitario, Valencia, Spain

WG Inhalational Sedation

Introduction

Since the introduction of the anesthetic conserving device (ACD) AnaConDa® (Sedana Medical, Sweden), inhalational ICU sedation is increasingly used in many European countries. AnaConDa® can be used with normal ICU ventilators, avoiding circle systems, soda lime and vaporizers.

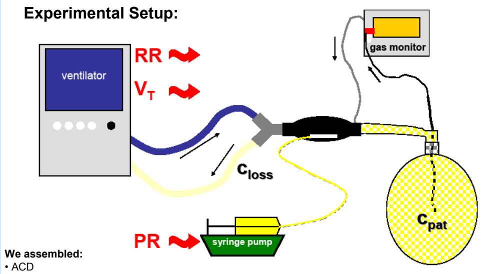


The ACD has two functional components: The anesthetic reflector (1) retains 90% of exhaled sevoflurane and resupplies it during inspiration (company information). A syringe pump delivers liquid sevoflurane into a porous rod called an evaporator (2).

Using a bench model, we describe the influence of ventilatory settings and infusion rates on the resulting mean anesthetic concentrations on both sides of the reflector under steady state conditions: c_{loss} (ventilator side) and c_{pat} (patient side)

Methods

Experimental Setup:



We assembled:
- ACD
- Ventilator (Puritan Bennett 840, Pleasanton, USA),
- syringe pump with liquid Sevoflurane,
- test lung (3 Liter chloroprene bag),
- Vamos gas monitor (Draeger, Luebeck, Germany), Sample gas was fed back.

We varied:
- RR=respiratory rates: 5-10-20-40 min^{-1}
- V_T =tidal volumes : 0.3-0.5-1.0 L
- PR =pump rates: 0.2-0.5-1-2-5-10-50 ml/h.

Each setting was left to equilibrate for >30 min.

We measured: c_{pat} in the middle of the bag.

We calculated: c_{loss} . In steady state the anesthetic delivered by the syringe pump (V'_{vapor}=PR * F) will escape through the reflector and be diluted by the expiratory minute volume (RR*VT + V'_{vapor}):

$$c_{loss} = PR*F / (RR*V_T + PR*F)$$

F is the factor for calculating sevoflurane vapor from liquid sevoflurane (F=207.6 under BTPS).
The PR must be inserted in the units [L/min]. The last addend (PR*F) may be omitted ($RR*V_T$>>>PR*F).

Results

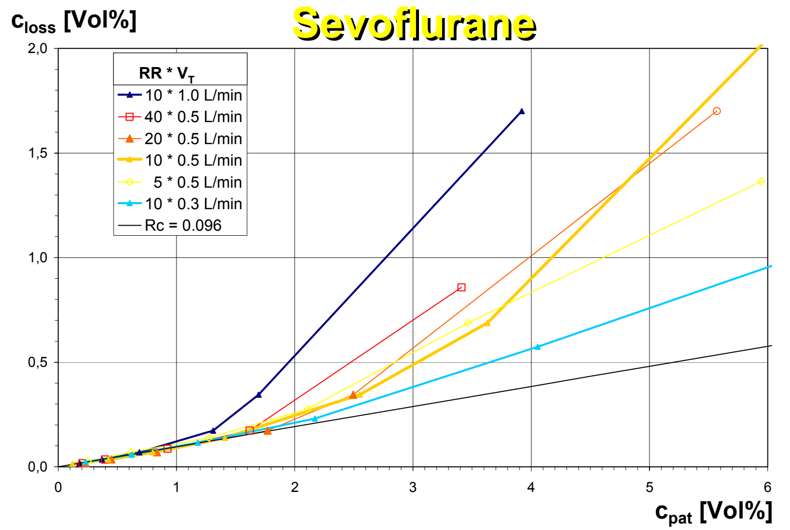


Figure 1: c_{loss}, the mean sevoflurane concentration on the ventilator side of the ACD, plotted against c_{pat}, the mean sevoflurane concentration on the patient side of the ACD. Ventilatory settings are described as respiratory rates (RR) times tidal volumes (V_T). Each point describes steady state conditions at different pump rates (PR). The straight line delineates the slope of the first parts of all curves.

At lower concentrations, there is a linear relationship between c_{loss} and c_{pat} independent of the ventilatory settings. The slope can be described by the ratio of the two concentrations (Rc = c_{loss}/c_{pat} = 0.096) which is constant for all ventilatory settings in the lower concentration range.

At higher concentrations, all curves bend upwards:
- the curve for the large V_T of 1 L around 1 Vol% (c_{pat} 0.7 to 1.3 Vol%),
- the curve for the small V_T of 0.3 L around 3.2 Vol% (2.2-4.1 Vol%).
- the four curves with the middle V_T of 0.5 L, but with differing RR, all ≈ 2 Vol%.

The RR shows little influence on the progression of the curves.
Exponential regression lines do not give good fits, because in the lower range, all curves seem exactly linear.

Discussion

In our bench model (steady state, no leaks, no patient uptake), we found a constant ratio of the concentrations c_{loss} to c_{pat} independent of the ventilatory settings at lower concentrations.

At higher concentrations, c_{loss} increased disproportionately. This may be interpreted as a ‚spill over': If during expiration the maximal capacity of the reflector is reached, no more molecules can be bound. More molecules will be carried through the reflector and be lost for the patient.

The maximal capacity of the reflector may be reached either by a large V_T with a low c_{pat} or a small V_T with a high c_{pat}:
- 1000 mL * 1.0 Vol% = 10.0 mL anesthetic vapor,
- 500 mL * 2.0 Vol% = 10.0 mL anesthetic vapor,
- 300 mL * 3.2 Vol% = 9.6 mL anesthetic vapor.

When anesthetic vapor spills over, performance of the ACD decreases. This offers some protection against an inadvertend overdose.

As c_{pat} is proportional to c_{loss} it follows (see Methods):

$$c_{pat} \sim c_{loss} \sim \frac{PR}{RR * V_T}$$

Summary

In this bench study of the ACD we describe the influence of ventilatory settings and infusion rate on the sevoflurane concentration in a test lung.

At large tidal volumes or high concentrations, ‚*spill over*' occurs.