THE IMPORTANCE OF PERIPHERAL VASOCONSTRICTION IN INFLUENCING BODY TEMPERATURES AND THE PART PLAYED BY CERTAIN ENVIRONMENTAL FACTORS: THE EFFECT OF INHALED GASES

LORD BROCK, J. M. SKINNER AND J. T. MANDERS

SUMMARY
Core and peripheral temperatures have been studied in 88 dogs of mixed breeds anaesthetized with pentobarbitone. Hyperventilation with cold, dry oxygen was associated with a decrease in peripheral temperature, whilst normoventilation was without effect.

METHODS
The operating room in which the experiments were carried out was provided with a double door and the window was protected by a wooden shutter, thus preventing draughts and radiation effects and minimizing incidental variations in ambient temperature.

Observations were made on 36 mongrel dogs (mean weight 10 kg; range 8–18 kg) and on 52 greyhounds (mean weight 25 kg; range 20–30 kg). Anaesthesia was induced with pentobarbitone 25 mg kg\(^{-1}\) i.v. in the mongrel dogs and 33 mg kg\(^{-1}\) i.v. in the greyhounds. The dogs were ventilated artificially with 100% oxygen via an endotracheal tube. Anaesthesia was maintained with increments of pentobarbitone 25–50 mg i.v. given at intervals of several hours. In 12 dogs, control observations were made first of all. Subsequently, each of these dogs was used for a definitive experiment.

Thick cotton socks were placed over all the paws of the dogs and the animals were covered with a space blanket (Dyde and Lunn, 1970) and a cotton towel. The dogs lay on a gel-mattress previously warmed to about 37 °C (Winder and Vale, 1970).

Measurements of arterial pH, \(P_{o_2}\) and \(P_{co_2}\) were made using suitable electrodes.

In the dogs, temperatures were recorded with a Sierex electrothermometer from thermocouples placed in the rectum, and bilaterally on the toes, ankles and calves. The ambient temperature was recorded also. Systemic arterial pressures, heart rate and e.c.g. were recorded using standard equipment (Devices). Venous pressures were measured using a water manometer. Cardiac output was determined using thermal dilution equipment (Devices) designed by Branthwaite and Bradley (1968).

The changes in the temperature were studied during normoventilation and during hyperventilation with either cold, dry gas or warm humidified gas.

RESULTS
Normoventilation
In dogs weighing 10–15 kg, ventilated with warm humidified gas at a tidal volume of 300–500 ml, at a frequency of 12 b.p.m., there were no changes...
in body or toe temperatures (fig. 1 is representative of the result in 22 animals). When cold, dry gas was used (15 dogs), there was a slight general cooling effect (figs 2A and 2B). In dog 155, the rectal temperature decreased from 37 °C to 36.3 °C in 1.5 h and the toe temperature from 36.2 °C to 35 °C (fig. 2A).

**Hyperventilation**

During ventilation with cold, dry gas at a tidal volume of 400–500 ml and a frequency of 18 b.p.m., significant vasoconstriction occurred as shown by a decrease in toe temperature accompanied usually by an increase in the core temperature. Figure 3 illustrates six examples of the 15 animals studied. Some of the animals were ventilated with carbon dioxide in oxygen to reduce the extent of the hypocapnia.

Vasoconstriction did not occur when the inspired gas was warmed and humidified (fig. 4). The two animals shown in figure 4 are representative of results obtained in 32 dogs using the heater humidifier.

In several dogs, hypocapnia was avoided by using mixtures of carbon dioxide in oxygen 3% (three dogs), 5% (two dogs) and 7% (four dogs). Figure 5 shows the results obtained in one dog, representative of the remainder. Despite hyperventilation and the production of hypercapnia (PCO₂ 9.7 kPa* and pH 7.17

\* 1 kPa = 7.5 mm Hg.

\* 1 kPa = 7.5 mm Hg.

**DISCUSSION**

We have demonstrated in this study that hyperventilation with unwarmed dry gas is a cause of peripheral constriction. From a practical point of view, if unwarmed dry gases are used during anaesthesia and unrestrained ventilation is added (as...
FIG. 3. Hyperventilation with cold, dry oxygen (with or without small concentrations of carbon dioxide) produced vasoconstriction. Dog no. 121: arrow † = death. Blood loss and samples—117 ml.
by vigorous manual compression of the reservoir bag for example), an undesirable state may result, especially in infants and children. Rashid and Benson (1967) have drawn attention to the dangers of unrecognized hypothermia in infants and children during anaesthesia in the absence of humidification. Harrison, Bull and Schmidt (1960) showed that if anaesthesia is administered to infants and children using a fresh gas flow of 6 litre.min⁻¹, there was a mean decrease in rectal temperature of 1.20 °C. In the neonate, the mean decrease was 3.8 °C (rectal).

An Editorial in *British Journal of Anaesthesia* (1970) discussed the undesirable effects of dry gases, but mentioned also the disadvantage of humidification, especially in infants or children, of a net gain of body water which may culminate in water intoxication. Also, warm humidified gas may be a cause of hyperpyrexia in infants (Graff and Benson, 1969). Furthermore, humidified air maintained at warm temperatures can be a breeding ground for pathogenic organisms.

Boyes and Howells (1972) reviewed the present situation with regard to humidification and they concluded that a critical assessment of the benefits deriving from humidifying anaesthetic gases has not been established. They stress that secretion retention had been neglected in previous discussions, but this tends to occur in every anaesthetized patient in whom humidification of the respiratory tract has been omitted. Knudsen, Lomholt and Wisborg (1973) assessed the incidence of pulmonary complications using dry, humidified anaesthetic gases in a controlled double-blind study in adult patients undergoing abdominal or transthoracic operations, or both. Eighty-four patients anaesthetized, on average, for 5 h were studied. No significant difference in complication rate was found between the humidified and the non-humidified groups. In both groups, all the complications were transient and harmless. It was concluded that no reason was found to justify the potential risks associated with routine use of humidifiers during anaesthesia.

In contrast, Forbes (1973) has studied the effects of humidifiers on mucus flow in the intubated trachea in greyhounds, using the rate of travel of a marker, lycopodium powder. His observations support the importance of adequate humidification in promoting and maintaining adequate mucosal flow. In addition, many authors have described the harmful effects on the mucosa of using cold, dry gases (Burton, 1962; Sara, 1965). In the first few hours after operation, an inflammatory reaction with hyperaemia of
the mucus membrane occurs. This is followed by a considerable increase in mucous secretion and if any further drying takes place, the mucus becomes very viscous and crusting may eventually occur in the bronchi (Burton, 1962). The ciliary action is impaired also by dry gases (Burton, 1962; Forbes, 1973) and by atropine.

In addition to these considerable features, the use of cold, dry gases is associated with heat loss.

Dery (1973), in a full and careful study of the heat and moisture pattern in the respiratory tract with a non-rebreathing system, demonstrated that during the inspiratory phase, the cool, dry gas mixture gains in temperature and body isothermia is attained at a distance usually of 15 cm below the carina. The relative humidity increases to 80% in the trachea, 90% in the main bronchi and 100% is attained in the lobar divisions. Isothermic saturation is reached at or near the carina in a conscious man breathing through his nose, at 10 cm below the carina during anaesthesia with a semi-closed circuit, and below the carina with a non-rebreathing system.

The loss of body heat by the delivery of unwarmed gases is small because of the very low specific heat (the specific heat of oxygen is 1.26 mj.cm\(^{-2}\)). In contrast, water vapour produces a much higher quantity of heat loss because the specific heat of water is 1.0 (2500 times greater than that of the gas mixture (Macintosh, Mushin and Epstein, 1963)).

ACKNOWLEDGEMENTS

We wish to record valuable technical assistance from Mrs Christine Mills and Miss Catherine Richardson. We are also very grateful to Miss P. Archer and Mr Patrick Elliott of the Department of Medical Illustrations, Guy's Hospital, for their preparation of the graphs of records.

REFERENCES


Die Bedeutung von Gefässverengungen für Körpertemperaturen, sowie die von gewissen Umweltfaktoren gespielte Rolle: Die Wirkung von eingetetmeten Gasedn

ZUSAMMENFASSUNG

Die Wirkung von eingetetmeten Gasedn

Die Bedeutung von Gefässverengungen für Körpertemperaturen, sowie die von gewissen Umweltfaktoren gespielte Rolle: Die Wirkung von eingetetmeten Gasedn

IMPORRANCIUSER LA VASOCONSTRICION PARA INFLUENCIAH LAS TEMPERATURAS CORPORALES Y EL PAPEL DESARRRROLLADO POR CIERTOS FACTORES AMBIENTALES: EL EFECTO DE LOS GASES INHALADOS

SUMARIO

Se han estudiado las temperaturas periférica y del núcleo en 88 perros de razas mezcladas, anestesiados con pentobarbital. La hiperventilación con oxígeno frío y seco fue asociada con un descenso de la temperatura periférica, mientras que la normoventilación no tuvo efectos.