Systemic oxygen consumption shows a 7% reduction per degree change in core temperature: an analysis of 828 blood gas results during cardiac surgery in 351 patients.

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Introduction

The use of an extracorporeal circuit to lower core temperature is a fundamental principle of organ protection during cardiac surgery. For other kinds of surgery, maintenance of normothermia under anaesthesia is favoured. The deliberate induction of hypothermia appears to be neuroprotective in association with cardiac arrest, but there is little published data on the relationship between core temperature and oxygen consumption. A retrospective analysis of 828 blood gas samples in 351 patients undergoing cardiac surgery shows a clear relationship between core temperature and systemic oxygen consumption, but raises more questions than it answers.

Methods

The perfusion data sheets of 351 successive patients undergoing cardiac surgery were analysed to determine systemic oxygen consumption. Every blood gas was analysed and correlated with the contemporaneous core temperature, and venous saturation recorded from the in-line venous saturation monitor. Total systemic oxygen consumption was determined, as well as O2 consumption per kilogram and per sq.metre of body surface area. Of the 828 samples, 200 were from female and 628 from male subjects . The venous saturation was used in calculation of total body oxygen consumption, and the values were not corrected for the isolated myocardium: values were divided by the recorded preoperative body weight and surface area.

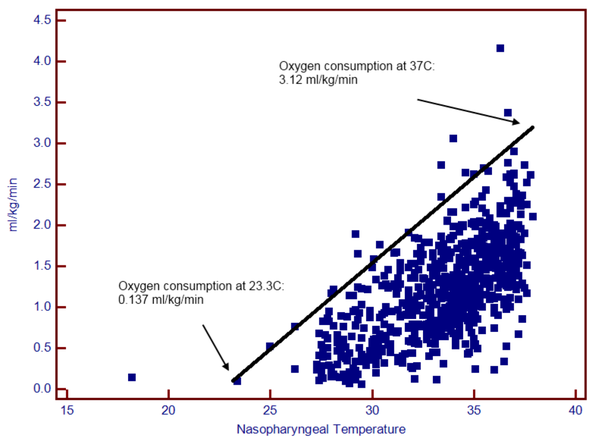

Figure 1. Systemic oxygen consumption calculated from in line venous saturation and 'arterial' gas samples in 351 patients undergoing open heart surgery. The upper limit of oxygen consumption describes a line with a gradient of 0.218 ml/kg/min per degree change in core temperature. This is a linear change of 7% per degree change in core temperature, consistent with the surgical rule of thumb that a 7C change in temperature represents a 50% change in O2 consumption

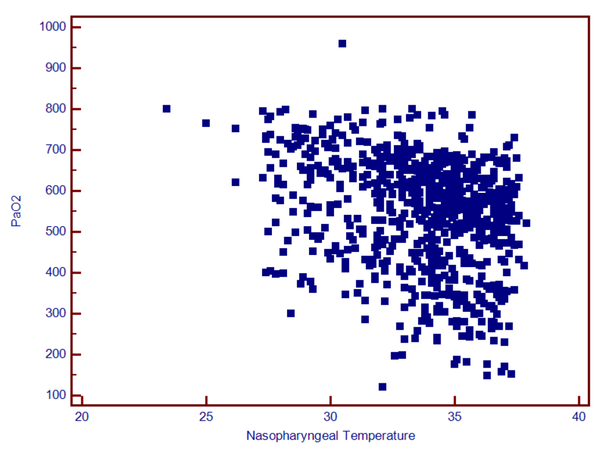

Figure 2. Arterial PO2 during cardio-pulmonary bypass in 351 patients. As oxygen consumption approaches zero(at 23C), the PaO2 approaches the ambient atmospheric pressure. If the PaO2 is higher than expected, and O2 consumption lower than predicted for a given core temperature, the systemic oxygen consumption must be less than the cellular oxygen requirements.

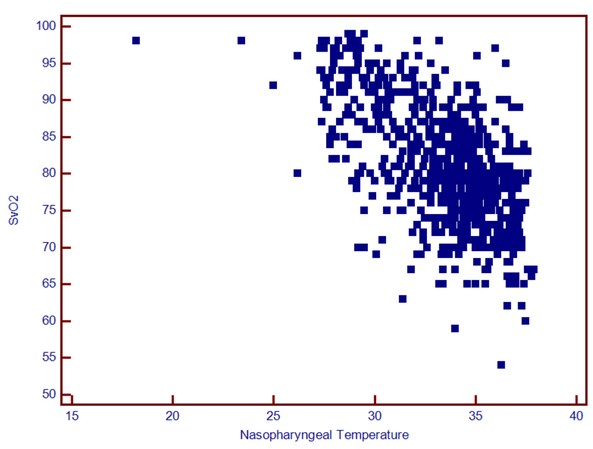

Figure 3. As systemic oxygen consumption falls, and PaO2 approaches ambient atmospheric pressure, the oxygen extraction approaches zero. The gradient of rising venous saturation with a falling core temperature coincides with the 7% fall in systemic oxygen consumption per degree fall in core temperature.

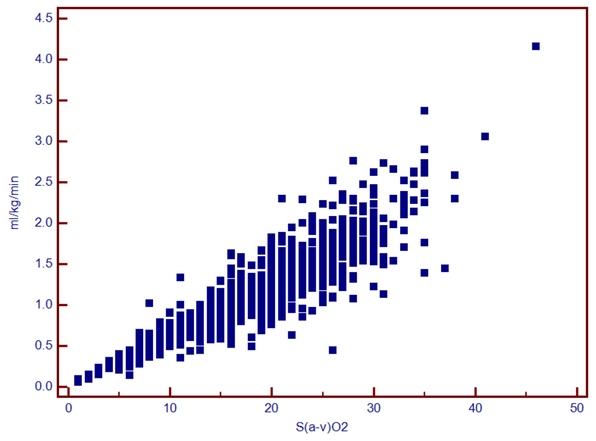

Figure 4. The extraction index approaches zero as oxygen consumption falls. At a normothermic oxygen consumption of 3 ml/kg/min the extraction index on cpb is 40%, compared to a 'normal' value of 25-30%, so the extraction index increases as haematocrit falls, but O2 consumption is usually subnormal when adjusted for core temperature

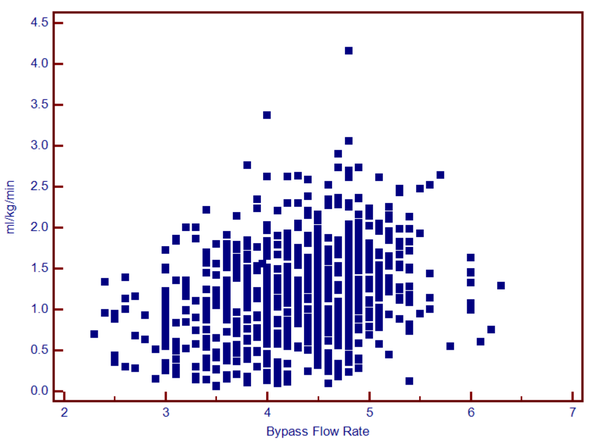

Figure 6. Increasing bypass flow rates ('cardiac output') appears to increase systemic oxygen consumption. Since CPB is associated with an acute fall in Hct of 40-60%, and a reduction in flow relative to normothermic CO, extraction index cannot compensate for the fall in oxygen delivery. If oxygen consumption is linearly related to core temperature, flow rates and Hct should be adjusted to reflect this.

Results

For every degree fall in core temperature, there is a 7% fall in systemic oxygen consumption, down to a core temperature of 23C. At a core temperature of 23C, the oxygen consumption was approx. 2% of the value calculated at normothermia (37C). Although there was a clear linear reduction in oxygen consumption, a large proportion of calculated values indicate a total oxygen consumption that is well below 'normal'.

Conclusions

A fall in core temperature consistently decreases systemic oxygen consumption. A decrease in core temperature below 23C yields no additional organ protection, and would appear to be beneficial only in ensuring that the temperature of individual organs is no greater than 23C, given that there will be temperature gradients between organs. The graphed data from 328 patients however raises the question of tissue oxygen availability, since a large number of patients had markedly 'subnormal' oxygen consumption. Given the relative hypotension if cardiopulmonary bypass, this raises the possibility that hypotension reduces systemic oxygen consumption by decreasing oxygen delivery. If hypothermia decreases oxygen consumption, it is likely that the adverse effects of hypothermia result from cessation of anaesthesia in a cold patient rather than hypothermia intra-operatively.