CORRESPONDENCE

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Anesthetic Requirements Decrease after Cardiopulmonary Bypass

To the Editor:—In a recent report by Antognini[1] goats anesthetized with isoflurane were noted to have a reduction in minimum alveolar concentration (MAC) (following cardiopulmonary bypass employing hypothermia and subsequent rewarming to 37° C) of approximately 20%. The author speculated that various properties related to hypothermia may explain the difference in isoflurane MAC before *versus* after cardiopulmonary bypass. We would like to offer another explanation, that MAC was reduced because of an effect related to cardiopulmonary bypass itself independent of any effect due to hypothermia. We previously have shown in the dog that enflurane MAC was reduced after normothermic cardiopulmonary bypass.[2] Subsequent investigation has shown that, in a partial-bypass model in the dog, this effect was independent of the role played by hypothermia and changes in arterial carbon dioxide concentration.[3] Although Antognini and Kien could not replicate our initial results,[4] the study by Antognini has demonstrated a difference in anesthetic requirements before *versus* after cardiopulmonary bypass. Taken together, the results suggest that MAC reduction following cardiopulmonary bypass is species-independent, agent-independent, and temperature-independent. Clearly, there is variability in the observation even when performed by the same investigator. What remains to be explained is the mechanism for the reduction.

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In Reply:—Although the 20% minimum alveolar concentration (MAC) reduction seen in my study[1] was not the principal finding, it raises an important question now addressed by Hall and Sullivan: Does cardiopulmonary bypass (CPB) alter MAC? Their interpretation of the various studies[1–4] is that MAC reduction after CPB is species-, temperature-, and agent-independent and therefore is due to CPB. Unfortunately, there are many confounding variables, so that simply "adding" the studies together may not result in a valid conclusion. A MAC reduction seen after CPB may be fleeting, and other variables (*e.g.*, hypothermia, duration of bypass) may accentuate or attenuate this manifestation. For example, differences in the CPB prime might explain the discrepant results, because Plasmalyte, which was used in the Hall and Sullivan[2] and Doak *et al.*[3] studies, contains acetate, which lowers MAC.[5] Furthermore, because acetate is metabolized quickly, its effect would be transient.

Taken together, I think that the results of these studies do not clearly answer the question, and further work is necessary.

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Change in Stroke Volume by Iced Temperature Injectate for Thermodilution Cardiac Output Determination

To the Editor:—Cold temperature injectate has been recommended for thermodilution cardiac output (TDCO) determination to enhance the signal-to-noise ratio, but several clinical studies have reported transient reductions in heart rate and blood pressure with the use of iced temperature injectate.[1–3] Stroke volume also may be altered but has not been studied to date. We examined the relative changes in heart rate and stroke volume during room temperature and iced temperature TDCO measurements.

After institutional approval and informed consent, six adult patients in the intensive care unit who required pulmonary artery catheterization were studied. TDCO measurements were obtained by manual injection of 10 ml D_5W through a closed delivery system. Heart rate (electrocardiogram) and noninvasive beat-to-beat stroke volume (SORBA CIC-1000 impedance cardiograph, Milwaukee, WI) were monitored during the injection of both iced (≤6° C) and room temperature (23° C) injectate. The order of injectate temperature was alternated with each patient. At each injectate temperature, two injections, made at 3-min intervals during the onset of an end-expiratory breathhold, were used to generate the cardiac output measurements; however, if the two measurements were not within 10% of each other, a third injection was performed. Hemodynamic values measured at the onset of injectate were used as baseline. Individual maximal responses in heart rate and stroke volume were selected during each TDCO and compared to baseline using Student's paired *t* tests. Two-way analysis of variance for repeated measures was used to determine the significance of hemodynamic changes. Values are expressed as mean ± SEM. Results were considered significant at $P \leq 0.05$.

TDCO using iced temperature injectate (8.6 ± 0.5 l/min) did not differ from that measured using room temperature injectate (8.6 ± 0.8 l/min). Table 1 summarizes maximal hemodynamic responses. Iced temperature TDCO was followed by a 5 ± 2% maximal reduction in heart rate ($P \geq 0.05$) and a 30 ± 8% maximal increase in stroke volume ($P \leq 0.05$). These responses were not observed during the use of room temperature injectate.

Our data showed a significant increase in stroke volume when iced injectate was used for cardiac output determination. However, unlike several other studies,[1–3] a reduction in heart rate was not seen. Heart rate slowing during iced temperature TDCO measurements has been attributed to local cooling of the sinoatrial node rather than a reflex-mediated autonomic mechanism.[1] Surgically induced autonomic blockade does not prevent iced temperature bradycardia,[1] and room temperature injectate delivered in a manner similar to iced temperature injectate does not elicit a comparable reduction in heart rate.[2] Our observed augmentation in stroke volume during iced temperature TDCO has not been previously documented in a clinical setting. The increase in stroke volume may be due to a prolonged diastole, resulting in an increase in cardiac filling (Frank Starling mechanism). We conclude from our limited study that iced temperature injectate has a minor effect on the heart, and if a slowing of heart rate does occur, cardiac output may be unaffected secondary to an augmentation in stroke volume. Further studies are needed to investigate these preliminary findings.

Table 1. Peak Hemodynamic Responses during Room Temperature (23° C) and Iced Temperature (≤6° C) Thermodilution Cardiac Output Measurement

	Baseline	Peak Response	Time (s) to Peak Response
Heart rate (b/min)			
Room temperature	88 ± 8	86 ± 8	2.5 ± 0.4
Iced temperature	88 ± 8	83 ± 9	3.8 ± 0.7
Stroke volume (ml/min)			
Room temperature	83 ± 16	94 ± 11	3.8 ± 0.9
Iced temperature	85 ± 15	111 ± 20*	4.3 ± 0.8

Values are mean ± SEM.
* $P \leq 0.05$ compared with baseline value.

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