The Slowing of Sinus Rhythm during Thermodilution Cardiac Output Determination and the Effect of Altering Injectate Temperature

ANDREW P. HARRIS, M.D.,* CLAIR F. MILLER, M.D.,† CHARLES BEATTIE, M.D.,† GILBERT I. ROSENFELD, CCPT, MARK C. ROGERS, M.D.‡

Bradycardia following injection of iced thermodilution solution recently was described in a patient having intraoperative cardiac output determinations. This heart rate response was attributed to sinus node cooling during iced injections. We studied the incidence of this finding by examining the intraoperative hemodynamic data in a group of surgical patients in whom cardiac output was being measured with iced thermodilution solution. In addition, we also studied the heart rate response to both iced and room temperature thermodilution injections in a second group of patients to determine if slowing of the heart rate during thermodilution injection is a cold-temperature-mediated response.

MATERIALS AND METHODS

This study was approved by the Joint Committee on Clinical Investigation of The Johns Hopkins Hospital.

The intraoperative hemodynamic strip chart recordings of 63 consecutive adult cardiac surgical patients in normal sinus rhythm were studied for evidence of sinus slowing (defined as a decrease of 10% or greater of preinjection heart rate) following iced thermodilution injections. Each patient required systemic and pulmonary arterial catheterization to assist in intraoperative management. Thermistor output curves, systemic and pulmonary arterial pressures, and electrocardiographic (ECG) leads II and V5 were recorded continuously on a multichannel strip chart recorder (Hewlett Packard)® at a paper speed of 2.5 or 10 mm per second. All cardiac output determinations were performed in triplicate with 10 ml iced (0°C) D3W, which was prepared by a method previously described to assure reproducibility. Only thermodilution injections made during periods of hemodynamic stability (i.e., before surgical incision) were studied. For each injection, the heart rate (determined by measuring R-R intervals) in the 20-s period immediately preceding the injection was compared with the heart rate in the 20-s period immediately following injection for the presence of sinus slowing and any associated change in systemic or pulmonary arterial blood pressure. The following data also were obtained: time from start of injection to change in R-R interval, time from injection to widest R-R interval, and time from injection until heart rate returned to preinjection rate.

For the second portion of the study, the effect of altering injectate temperature on the heart rate response was studied intraoperatively in a separate group of nine surgical patients in sinus rhythm. These patients demonstrated a 10% or greater decrease in heart rate following an injection of iced thermodilution solution. These nine patients were entered into a protocol consisting of three 10-ml thermodilution injections for a subsequent cardiac output determination: the first injection with iced (0°C) solution, the second injection with room temperature (15–20°C) solution, and the third injection with iced (0°C) solution. The sequence was planned in order to reconfirm that these patients indeed would have sinus slowing in response to iced saline both before and after the room temperature injection was made. The heart rate returned to baseline between each injection. The multichannel strip chart recordings were studied during each of these 27 injections for sinus slowing, magnitude of slowing following injection, and any associated changes in systemic or pulmonary arterial pressure.

Data were analyzed by two-way analysis of variance and Duncan’s multiple-range test. All data are expressed as mean ± SEM. A P value ≤ 0.05 was considered significant.

RESULTS

Study 1—The Incidence of Sinus Slowing with Iced Solution. In the 65 patients examined to determine the incidence of heart rate slowing following iced injectate, a decrease of 10% or greater of preinjection heart rate was observed in 14 patients (22%). The decrease in heart rate began 2.8 ± 0.03 s after the start of injection, the maximal decrease occurred at 4.7 ± 0.4 s, and heart rate returned to baseline at 10.2 ± 0.6 s. The mean systemic and pul-
monary arterial pressure did not change from preinjection baseline during any injection.

Study 2—The Effect of Altering Injectate Temperature. In these nine patients, the first iced (0°C) injection resulted in a 10.4 ± 1.0% decrease from preinjection heart rate, the room temperature (15–20°C) injection decreased heart rate 4.4 ± 1.1%, and the repeat iced (0°C) injection decreased heart rate 9.9 ± 1.1% (see fig. 1). The heart rate decreased significantly from baseline following both room temperature and iced injection, however, the room temperature injection decreased heart rate significantly less than the two iced injections. Systemic and pulmonary arterial pressures did not change during any injection.

**DISCUSSION**

This study demonstrates that slowing of the sinus heart rate occurs frequently following injection of iced thermodilution solutions. Twenty-two per cent of our first group of patients demonstrated transient decreases in heart rate that did not alter any other measured hemodynamic variable. The possibility that acute changes in heart rate during injection could adversely affect the accuracy of cardiac output measurements cannot be evaluated from our study.

In the second group of patients demonstrating heart rate slowing with iced injection, use of room temperature injectate caused a smaller change in heart rate. This finding suggests that sinus slowing is a cold-temperature-mediated response. This conclusion is consistent with the experimental studies by Marshall, in which cooling of isolated sinus node cells of rabbit atria resulted in a marked increase in the duration of the action potential and a marked decrease in the slope of Phase 4 diastolic depolarization. Since many patients do not demonstrate sinus slowing during iced injection, we suggest that either the intracavitary position of the right atrial port does not consistently direct the cold injectate toward the sinus node or that a heterogeneous response to sinus node cooling occurs among patients. The decrease in heart rate that occurred with room temperature injection is also consistent with our conclusions, because the room temperature injectate was actually quite cold when compared with body temperature. We cannot exclude the effect of pressure exerted by the injectate stream on the sinus node or atrium contributes in some minor way to the heart rate slowing observed. The only way to rule out an effect of pressure is to inject body temperature solution, and, since cardiac outputs cannot be determined with body temperature injectate, we did not feel it was appropriate to test this in our patients.

In conclusion, transient slowing of the sinus heart rate occurs frequently during injection of 10 ml iced thermodilution solution, and this response is most likely mediated by cold temperature. Since thermal determinations of cardiac output can be made accurately and reproducibly with room temperature as well as with iced injectates, our data would support the routine use of room temperature solutions.

**REFERENCES**

1. Nishikawa T, Dohi S: Slowing of heart rate during cardiac output measurement by thermodilution. ANESTHESIOLOGY 57:538–539, 1982