
Perfusate Temperature Variation in the Extracorporeal Circuit

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Abstract

During twelve consecutive pediatric open-heart procedures utilizing the Harvey 1500 oxygenator with internal temperature probe ports, temperatures were simultaneously measured from the oxygenator and the perfusion line. An observation is presented of varying temperatures as measured within the extracorporeal circuit. During these clinical runs and an *in-vitro* study, temperature measurements obtained from the oxygenator's internal ports yielded values which varied predictably from those obtained in the perfusion line. Ambient temperature proved to have a measurable effect on metal in-line probe jackets, although residual differences existed after insulation.

Introduction

The significance of monitoring perfusate temperature during cardiopulmonary bypass has been well documented.^{1,2} A variety of methods has been used to determine blood temperatures. The most recent method is the utilization of arterial and venous temperature probe ports incorporated into the oxygenator design. The new elliptical Harvey* 1500 bubble oxygenator provides stainless steel temperature ports in both the arterial reservoir and at the venous inlet to the oxygenator. In some instances, however, these sites may yield different temperature readings than do probes placed directly in-line. During twelve pediatric clinical

perfusions in which the Harvey 1500 was chosen for its heat exchange characteristics, we have simultaneously recorded arterial and venous temperatures both in-line and in the oxygenator in order to identify and evaluate any temperature discrepancies.

Methods and Materials

Twelve consecutive patients with congenital heart disease undergoing cardiopulmonary bypass utilizing the Harvey* 1500 were selected for this study. In all cases, the prime consisted of lactated Ringer's solution, human albumin, whole blood and or packed red blood cells, as necessary to maintain an adequate hematocrit. Heparin, mannitol, sodium bicarbonate, and calcium gluconate were included in the prime as mandated by patient size and laboratory values. Hypothermia was utilized in all cases; the water temperature was regulated via a Sarns** external heater/cooler (P/N 11160).

All patients were initially anticoagulated with 4 mg/kg of beef lung heparin. The superior and inferior vena cavae were each cannulated and used for gravity venous return. Arterial blood was returned via an aortic root cannula. All cases were carried out using a Cobe*** Stöckert pump 80215 equipped with temperature and pressure monitors. The circuit materials included Cobe*** perfusion tubing, an arterial line filter**** and Cobe*** cardiomy reservoir with a Swank† filter.

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** Sarns Inc., Ann Arbor, Mi. 48103.

*** Cobe Laboratories, Inc., Lakewood, Co.

**** Pall Biomedical Products, Glen Cove, N.Y. 11542, or Extracorporeal Medical Specialties, Inc., Norristown, Pa. 19403.

† Swank.

TABLE I
Summary of Patient Data

Pt	Age	BSA	Pump Time	Flows	Arterial		Venous	
					C	W	C	W
1	15 Y	1.36	57'	2440-3000	2.22 ± 1.33	4.28 ± 1.19	—	—
2	12 Y	1.29	44'	2360-3000	1.90 ± .65	2.80 ± .56	—	—
3	9 Y	.94	64'	2020-2440	1.57 ± 1.45	3.23 ± .42	3.17 ± 3.35	4.80 ± 1.00
4	12 Y	1.11	133'	2000-3030	1.62 ± .93	2.10 ± .33	1.75 ± .46	3.50 ± 1.28
5	9 Y	1.07	97'	2290-2750	.48 ± .50	2.37 ± .53	1.40 ± 1.16	4.87 ± 1.13
6	10 Y	.99	172'	1670-2500	1.70 ± .90	1.90 ± .72	.74 ± .31	1.50 ± .85
7	3½ Y	.71	75'	1770-3060	1.10 ± .51	1.23 ± .55	2.84 ± 1.46	4.53 ± 1.85
8	11 Y	1.16	26'	2600-3200	1.60 ± .14	2.83 ± .21	3.75 ± .35	5.93 ± .58
9	7 Y	.88	90°	1700-2370	2.40 ± 2.95	1.72 ± .34	1.63 ± 1.69	4.57 ± .76
10	6 Y	.79	105'	1650-2160	.95 ± .73	4.57 ± .29	.47 ± .30	2.92 ± .52
11	4 Y	.62	80'	1670-2480	.62 ± 1.12	1.61 ± .91	1.15 ± 2.06	4.85 ± 2.00
12	3½ Y	.84	49'	1630-2480	1.93 ± 1.29	1.78 ± .49	3.10 ± 2.52	4.91 ± 1.87

Values are the mean difference between sites (oxygenator versus lines) during cooling (C) and warming (W).

Blood gases, chemistry and hematology reports were obtained before, during and after bypass. The patient's coagulation status was assessed continuously while on bypass via activated clotting time determinations run in a Hemochron^{††}. Temperature measurements were obtained from both the H-1500* probe sites and from commercially available in-line temperature probe jackets^{†††}; one was located six inches proximal to the venous inlet and the other six inches distal to the arterial outlet.

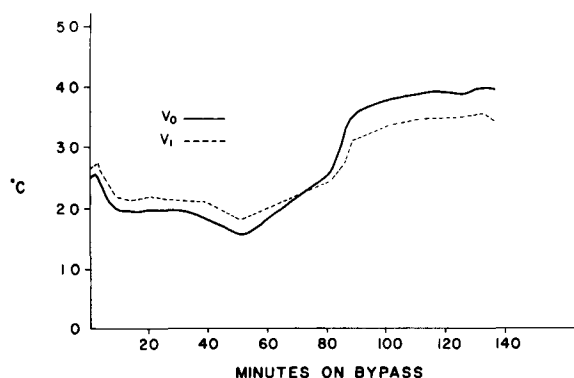
A control run utilizing an arterial-venous loop was performed to eliminate any patient variables. In the control run, a Harvey* 1500 was primed with 2 liters of lactated Ringer's. In order to simulate a clinical extracorporeal bypass, the perfusate temperatures, gases, and flow rates were continually adjusted to those of the patient whose core temperature spanned the widest range (Patient #4). The in-line probes were then isolated with styrofoam to evaluate the influence of ambient temperature on the probes. All probes were of the YSI^{††††} 500 series.

Results

Twelve pediatric patients were perfused with the William Harvey* 1500 bubble oxygenator while both in-line and in-oxygenator blood temperatures were measured and recorded. A summary of patient perfusion data appears in Table I. Patients #1 and #2 had

only arterial gradients measured as no venous in-line probe was available at this time. Temperature data are expressed as the mean difference between the two sites (oxygenator and line) during cooling (C) and warming (W). Measurement of prime temperature before bypass showed essentially no difference in temperature (.1°C or less) between any of the probe sites. It should be noted that the water recirculator was off at this time. Individual data points of patient #4 have been graphically displayed because this patient had the widest span of core temperature (Graphs 1 and 2).

In the control run, the discrepancy between oxygenator and line temperatures averaged 1.4°C during cooling. Upon rewarming, the average difference between sites increased. A temperature discrepancy of up to 6.7°C occurred in one instance with the arterial reservoir being warmer than the arterial line. When

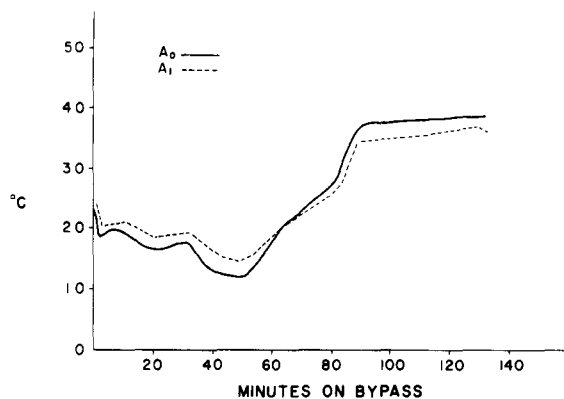


GRAPH 1. Venous oxygenator (V₀) and venous line (V₁) temperature measurements of Patient #4. Note the greater area between the two when warming.

†† International Technidyne Corp, Metuchen, N.J. 08840.

††† Cardiovascular Instruments, Waltham, Ma. 01880.

†††† Yellow Springs Instruments, Inc., Yellow Springs, OH 45387.



GRAPH 2. Arterial oxygenator (A_0) and arterial line (A_1) temperature measurements of Patient #4. Note trend reversal concurrent with rewarming.

evaluating the effect of room temperature on the line probes, it was discovered that insulating the probes decreased the measurable difference between sites, but there remained a 2.6°C difference in temperature between oxygenator and line, with a six-inch separation of probe sites.

Upon initiation of clinical bypass, there developed in most instances a discrepancy between oxygenator and line temperatures at both arterial and venous sites (See Graphs 1 and 2). While in the cooling mode, the oxygenator temperature probes yielded values slightly lower than their respective in-line probes, the average difference being approximately 1.5°C . During warming the temperature difference between probe sites was accentuated. There was a clear trend toward higher oxygenator temperature readings relative to the in-line readings. While warming, the difference encountered between arterial probe sites averaged 4.24°C (without insulation).

Discussion

Simultaneous recordings from in-line and intra-oxygenator temperature probes have demonstrated a difference in perfusate temperature at these two sites. It should be noted that the in-line temperature probes are housed in metal jackets which are exposed to room

air. This affects temperature determinations at these sites. Tamura, et al.³ have recently reported the use of a zero-heat flow noncontact transducer for measuring perfusate temperature which eliminates any external temperature influence. The oxygenator probe sites may be influenced by their proximity to the heat exchanger as well as the thermal conductivity of the blood. The efficiency of the integral heat exchanger is determined by blood to water flow rates as well as the water temperature. Thus, it is prudent to avoid creating an excessive heat transfer rate, especially at low flows.

The perfusionist must be aware that temperature variations may occur throughout the system with various temperature monitoring techniques. Water temperature adjustments based on blood temperature at a site removed from the heat exchanger may be at variance with the temperature of blood in contact with the heat exchanger. Over-heating of blood can cause severe hemolysis⁴, and excessive gradients may result in the formation of microbubbles as oxygen solubility changes with temperature¹.

Conclusion

This study shows a difference in perfusate temperature measured at different sites in the extracorporeal circuit. The perfusionist must be aware of specifications of individual circuits and of temperature monitoring devices. The peak blood-to-water gradient must be accurately determined and consistently maintained. Rapid rewarming with unsuspected high gradients may be deleterious and should be avoided.

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