Title : HEAT DOSAGE VS. DISTRIBUTION DURING REWARMING ON C-P BYPASS

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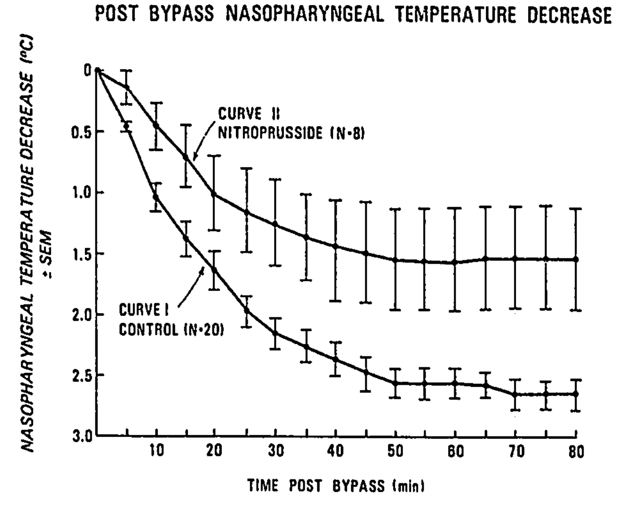
Emergence from previously hypothermic cardiopulmonary bypass (CPB) is usually followed by body temperature decreases, despite rewarming on bypass to nasopharyngeal temperatures (NPT) of 37°C. Upon recovery from neuromuscular blockade, resultant shivering may severely increase oxygen delivery demands. We hypothesized that variations in either administered dosage or distribution of heat during rewarming might explain the post-bypass hypothermia. Efficacy of warming blankets and effect of ambient air temperature on post-bypass NPT decreases were also studied. Sodium nitroprusside (SNP) was administered during rewarming on bypass to 8 of the 28 patients studied to attempt to change both heat delivery and distribution.

Methods: Adequacy of rewarming was assessed by NPT decreases post-bypass. Great toe temperature increases during rewarming provided a measure of peripheral heat distribution. Heat dosage* was summed for each minute of the entire rewarming period and expressed as total Calories administered, corrected for depth of intra-bypass hypothermia. Ambient air temperature was recorded initially and held constant (18-23°C). Warming blanket surface and water outlet temperatures were recorded. In 20 patients, no attempt was made to alter usual practice (Group Ia - with warming blankets, n=16; Group Ib - without warming blankets, n=4). Nitroprusside was given during rewarming to 8 other patients (Group II). SNP dose was maximized within two constraints, namely maintaining mean arterial pressure > 70 mmHg, and increasing pump flow until arterial inflow line pressure reached approximately 300 mmHg. This resulted in SNP doses of 3.4 ± .8 (SEM) μg/kg/min.

Results: Post-bypass NPT decreases are shown in Figure 1. NPT was similar in both groups of patients at the termination of bypass (37.3°C - Group I, 37.2°C - Group II). Despite a wide range of total heat dosages (12.4-33.5 kcal/m²·°C of bypass hypothermia), there was a similar and significant decrease in NPT in every patient in Group I, averaging 2.64 ± .15°C (SEM) at 80 minutes. This was not related to ambient air temperature or to use of warming blankets with surface temperatures which averaged 39.3°C. In Group II (with SNP) post-bypass NPT decrease was significantly less than that in Group I at and beyond 5 minutes. At 80 minutes post-bypass, average Group II NPT decrease was only 1.53 ± .42°C (SEM), compared to the 2.64°C decrease noted above in Group I ($p < .01$). Great toe temperature increased to an average of only 27.3°C in Group I, on bypass after rewarming; whereas with SNP, great toe temperature averaged 32.5°C at that time ($p < .02$). No significant differences were found between groups I and II with respect to total heat administered, warming blanket temperatures, rewarming times, or heat content at both termination of CPB and 45 min post-bypass. Ambient air temperature, in fact, averaged less (19.4°C vs 20.9°C, $p < .01$) in Group II, the group which maintained higher post-bypass NPT. Although pump flows were greater (12%, $p < .01$) in Group II, heat delivery was not, when summed over the entire rewarming period.

Conclusions: 1) SNP-vasodilation on bypass resulted in increased efficacy of rewarming, indicated by less post-bypass NPT decrease and greater peak rewarming peripheral temperature; 2) post-bypass NPT decrease was not altered by ambient air temperatures between 18 and 23°C; or by the use of warming blankets. Because SNP-vasodilation during rewarming significantly increased peripheral temperatures but did not increase total delivered heat dose, or prolong rewarming time, we further conclude 3) that adequacy of rewarming was more related to distribution of heat than to total heat dosage. The administration of SNP, coupled with increased pump flows, is recommended as a simple procedure to increase efficacy of rewarming during bypass.

Figure 1



$$\text{Heat dosage} = \sum_{t_0}^{t_w} \frac{\left[\begin{matrix}\text{Perfusate}\\ \text{temp}\end{matrix} - \begin{matrix}\text{NP}\\ \text{temp}\end{matrix}\right]\left[\begin{matrix}\text{Pump}\\ \text{flow}\end{matrix}\right]\left[\begin{matrix}\text{Blood}\\ \text{Specific}\\ \text{Heat}\end{matrix}\right]}{\left[\begin{matrix}\text{Body}\\ \text{Surface}\\ \text{area}\end{matrix}\right]\left[\begin{matrix}\text{Degree of bypass}\\ \text{hypothermia}\end{matrix}\right]}$$

Where $t_0 - t_w$ = Time during rewarming, dosage summed q. 1 min.