The (Wind) Chill Factor Controlled

THE THERMAL EFFECTS of hemodialysis and of related blood purification techniques on hemodynamic stability have been known for about 20 years, owing to the groundbreaking work by Maggiore et al., who showed the value of cool dialysate and therefore blood cooling in this phenomenon. However, it is only recently that the mechanisms and the relationships between hemodialysis and its thermal effects have become better understood and that approaches for dealing with this problem have been optimized.

While initial investigations focused on dialysate temperatures and on different treatment modes, subsequent studies recognized that it was not only dialysate temperature to which one had to pay attention. Patients with low to subnormal body temperatures particularly showed improved hemodynamic stability when treated with low dialysate temperatures (35°C). However, although patient temperatures are important, they are not the only confounding factor to be considered.

It may be instructive to consider the impact of dialysate temperature, which is still the focus of most studies in this field, in comparison with climatic wind chill factors. Even though the actual air temperature is not affected by wind speed, the removal of thermal energy from the skin largely depends on the flow of air past the body surface, and the extra cooling and heat transfer provided by such forced convection will determine how the body senses and controls temperature.

In analogy to the effects caused by wind chill, extracorporeal cooling (or heating) provided by hemodialysis depends not only on dialysate temperature, but also on convection, i.e., extracorporeal blood flow. In fact, the rate of cooling is proportional both to the extracorporeal blood flow and to the arterio-venous temperature gradient. Thus, at the same dialysate temperature, the degree of cooling may be quite different in both conventional and high-efficiency treatments because of different blood flows. Therefore, to control for such “environmental” effects, it is necessary to focus on extracorporeal heat flow instead of dialysate temperature.

Based on the concept of minimally perturbing the physiologic system, it appears straightforward neither to remove nor to add thermal energy through the extracorporeal circulation. Such a treatment is called “extracorporeally thermoneutral.” A thermonutral treatment is achieved by minimizing the arteriovenous temperature gradient in the extracorporeal circulation by corresponding adjustments in dialysate temperature. This approach has been followed in a few studies, resulting in patient temperatures increasing by approximately 0.5°C throughout dialysis without any exchange of heat between the extracorporeal system and the patient. It must be concluded from these results either that the production of metabolic heat was increased in the patients or that the dissipation of heat from the patient surface had decreased during hemodialysis, or that a combination of changes had occurred. Whatever the reason for the increase in temperature with extracorporeally thermonutral hemodialysis, the increase in body temperature by 0.5°C must have led to accumulation of thermal energy. Since an increase in body temperature is expected to increase cutaneous blood flow and to decrease total peripheral resistance, this type of thermonutral hemodialysis may indeed favor hypotensive episodes and do more harm than good.

The alternative major approach would be to adjust the removal of thermal energy so that there is no heat accumulation in the patient. This goal can be achieved by controlling for a constant body temperature. Such a treatment is called “isothermic.” Since body temperature is narrowly controlled by physiologic mechanisms, an isothermic procedure is in perfect support of the physiologic control mechanisms. In fact, such a control is unique in current hemodialysis as...
both the extracorporeal adjustments and the physiologic mechanisms jointly operate on the same control variable. Such control may indeed be called a physiologic feedback control mechanism.

In this issue of the Journal, a report by Maggiore et al documents the hemodynamic benefits of isothermic dialysis compared to the thermoneutral treatment mode delivered in 95 hypotension-prone dialysis patients. The study stands out in this area of dialysis research for the number of patients studied and for the comparison of the effects of thermoneutral and isothermic treatment modes. This comparison makes the results independent of confounding variables such as absolute body temperatures, blood flows, or dialysate temperatures.

As expected, body temperatures increased by 0.47°C ± 0.24°C with thermoneutral treatments, and the 50% incidence of intradialytic morbidity events was not affected when compared to the control period. However, using isothermic treatment modes (ΔT = 0.01°C ± 0.16°C), thermal energy was removed from the patients at a mean rate of 0.90 ± 0.35 kJ/(kg*h), amounting to 24% of estimated energy expenditure. This was accompanied by a decrease in the incidence of intradialytic morbidity events by 25%.

Isothermic treatments involved considerable cooling but did not affect the dose of delivered dialysis measured by Kt/Vurea, as might be expected from the alterations in regional blood flow distribution. This finding is in accordance with results from previous studies and can be explained by the reduction in hypotensive episodes, which are in themselves known to augment compartment effects and reduce Kt/Vurea.

One aspect deserves special attention. The drop in dialysate temperature developed gradually throughout dialysis and the minimum dialysate temperature of 35.7°C never reached the lower levels used in many previous studies. This finding probably explains the good tolerance of the treatment. Is this good tolerance an indicator of optimal care in this aspect of dialysis? One can think of treatment modes in which extracorporeal cooling exceeds the requirements for an isothermic treatment so that body temperature eventually falls. We do not know whether there are any benefits to be expected from such a prescription. However, a control to merely lower body temperature abandons the concept of physiologic feedback control, as under these circumstances the extracorporeal control system is working against the major influence of physiologic temperature control. Unless there is a resetting in the hypothalamic thermostat during hemodialysis, which might be linked to the removal of uremic toxins or to other aspects of the dialysis procedure, the attempt to lower body temperature by the extracorporeal device can be expected to be counter-regulated by the much more powerful internal temperature control mechanisms. Patients can be expected to start shivering and feel uncomfortable which is likely to defeat one of the objectives of an optimized dialysis treatment namely to minimize the perturbation of the dialysis patient.

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REFERENCES


