A “Virtual” Blood Gas Electrode for Use During Cardiopulmonary Bypass

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INTRODUCTION

We describe the development of a “virtual” blood gas electrode system intended for use during cardiopulmonary bypass (CPB). The electrode functions in real time and predicts the patient’s arterial and mixed venous blood gas results every 500 ms. It takes as its primary inputs the settings of the heart-lung machine (FiO₂, sweep gas rate, pump flow) and the patient’s hematocrit and metabolic rate. The electrode system incorporates integrated computer models of the oxygenator in use during the case and the patient’s arterial, venous, and tissue pools. The architecture of the model is a development of that described by Dickinson (1) and is shown schematically in Figure 1.

EVALUATION

The electrode is currently being validated in vitro against existing physiological computer models and in vivo using a Terumo CDI 500 (Terumo Cardiovascular Systems Corp., Ann Arbor, MI) blood gas analyzer (Figure 2). Preliminary results suggest that the performance of modern, hollow fiber artificial lungs is remarkably consistent and is amenable to modeling as described by Riley and Courand (2).

OTHER APPLICATIONS

The electrode has other possible applications in perfusion practice. These include evaluation of therapeutic

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Figure 1. Virtual blood gas electrode system architecture.
strategies, use in simulation systems, use in intelligent alarm systems, and evaluation of new products or techniques.

During the course of the presentation, examples of the evaluation of therapeutic strategies (such as the impact of different degrees of hypothermia on the survivability of arrest) will be examined. The use of the electrode in a software implementation of a veno-venous extracorporeal membrane oxygenation (ECMO) simulation system will also be demonstrated.

REFERENCES


Figure 2. An example of a real-time prediction of PaO₂. In a patient on stable CPB at 32°C the effect of reducing the inspired oxygen concentration from 100%–61% has been demonstrated. The PaO₂ measured by an inline CDI 500 (dotted line) has been compared with the PaO₂ prediction of the virtual electrode (solid line). During the period of exposure to the lower FiO₂, note how the PaO₂ falls from about 460 mmHg to about 230 mmHg in both cases.