POLYMER ARTICLES FOR ARTIFICIAL BLOOD CLEARANCE

A. I. Khaitlin

Artificial blood clearance is used to purify a patient's blood from toxic agents, bring ion content to optimum level, and remove excessive water. This versatile method of treatment is of significant interest for reanimatologists, nephrologists, cardiologists, pulmonologists, oncologists, and even psychiatrists (for treating schizophrenia). Until recently, patients with terminal kidney failure had quite unfavorable prognosis; now more than 400,000 patients presently use artificial kidney life support on a regular basis (2-3 times per week), the majority of them remaining active with minimal or no disability.

The widespread use of apparatuses for artificial blood clearance (ABC) in contemporary medicine is due to their superb clinical performance (stabilization of blood composition, detoxication, and ultrafiltration), safety (lack of side effects related to unfavorable influence of medical hardware on physiological and/or psychological status of patient), and availability [1-3].

The functional effect of artificial blood clearance is achieved by material, energy, and combined (material plus energy) control media which are produced in control elements of artificial organs and interact with blood in the executive elements (EE) of the organs in two ways:

1) direct interaction with blood in material-controlled EE made as closed tanks (columns) filled, for example, with sorbent; or in energy-controlled EE made as flow chamber, where blood receives either mechanical (gravitation plasmapheresis) or electrochemical (electrochemical oxidation) energy;
2) indirect interaction with blood through artificial membranes under energy control (ultrafiltration) in hemo- and plasmafiltration units or under combined material (dialysis) and energy (ultrafiltration and thermoregulation) control in dialyzers.

Systems for extracorporeal artificial blood clearance are brought to the patient's cardiovascular system through catheters, needles, three-way connectors, and tubing, which, like EE of artificial organs, are usually disposable and made of plastic. Similar disposable elements are used for blood perfusion.

Foreign manufacturers offer various disposable elements for artificial blood clearance. The diversity of the elements is due to the specific goals of blood clearance and specific functions of the equipment. The tubing design depends especially on the type of equipment used.

Therefore, the common view of connecting elements being unimportant expendable material should be reconsidered, because they significantly affect the performance of the equipment for blood clearance. To achieve maximum efficiency of blood clearance and to avoid undesirable losses of time and materials, the connecting elements should be designed to fit various specialized devices, rather than have one universal design. Comparative analysis of various connecting elements produced by different manufacturers and the general conception of their structure-function relationship in biotechnical systems should be useful for attaining more effective artificial blood clearance.

The demand for disposable connecting elements is enormous. More than 50 million dialyzers supplied with tubing and needles are required annually only for chronic patients. Automated production of connectors can satisfy such demand, although manual assembly of tubing sets is the most laborious stage. Constant progress in technology allows some important, although secondary, problems to be solved: increase production efficiency, save plastic raw material, reduce cost. However, the cardinal solution of the problem can be attained only by system design and compromise structure of ABC, where both hardware and disposable elements reciprocally interact to implement various methods of blood clearance.

The goal of the present work was to analyze the functional role of disposable elements in ABC and to elucidate their effect on the performance of ABC with minimal design redundancy.
Fig. 1. Blood perfusion: a) two connecting elements; b) one connecting element. CE1 and CE2, connecting elements; T, three-way connectors; M1, input (arterial) tubing; M2, output (venous) tubing; EE, executive element of artificial organ.

Fig. 2. Tubing for artificial blood clearance: a) input tubing with minimum number of elements; b) output tubing with minimum number of elements; c) input tubing with maximum number of elements; d) output tubing with maximum number of elements.

Blood perfusion through EE of any artificial organ (Fig. 1) can be arranged using two (see Fig. 1a; CE1 and CE2) or one (see Fig. 1b; CE1) connecting element and only one input (arterial) and output (venous) tubing (M1 and M2, respectively). The hydraulic diagrams of the tubing are shown in Fig. 2.

Extracorporeal transport of physiological liquids (blood, substitute solution) in contemporary ABC is performed by roller pumps. Mechanical energy is transferred to moving liquid in roller segments RS1.1 during blood perfusion with one or two connecting elements, in RS1.2 or RS2.1 during two-pump perfusion with one connecting element, and in RS2.2 during infusion of substitute solution.

The infusion line IL1 is used for infusing drugs (e.g., heparin) which are transported either by the roller pump incorporated into the infusion line IL1 or by an injection dispensing pump connected to the infusion line. Injection units IU1, IU2.1, and IU2.2 allow additional injection of drugs during perfusion.