CONTEMPORARY MEANS FOR EXTRA-RENAL BLOOD PURIFICATION USED ABROAD

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In medical practice, different means of extra-renal purification of blood are used effectively for partial or complete temporary replacement of lost excretory function of the natural kidney. These means became most widely used during a lengthy period (10-15 yr) when they maintained the lives of thousands of patients with chronic renal insufficiency. In these patients, extra-renal purification of blood was carried out 2-3 times per week (roughly 150 procedures a year). One should noted the furious tempo of work in this sphere of medical engineering: Practically every year new models of the apparatuses appear, necessitating a timely evaluation of their level of technology and current developmental trends.

An analysis of apparatuses exhibited at the "Public Health-80" international exhibition showed that the level of technology of contemporary apparatuses is characterized by the following features:

- automation of operation
- use of disposable elements conducting blood (dialyzers, hemofiltration units, and connecting lines);
- individualization of the method of extra-renal purification of blood (rejection of centralized systems, more and more widespread existence of apparatuses belonging to one person);
- heightened attention to the safety of the procedure of purification;
- realization of a design for an apparatus that can be used in fixed locations — in clinics or at home (models of portable apparatuses were not presented).

Regarding developmental trends for these apparatuses, one should note the following points:

1) **Besides** the methods of **hemodialysis** and peritoneal dialysis which have already become traditional, new methods of ultradiffusion and hemofiltration are being put into effect in these apparatuses;
2) requirements that the process of purification be physiologic are being strengthened;
3) to a greater and greater degree, the parameters which directly or indirectly characterize the normalizing action of extra-renal purification of blood on the human organism are beginning to be defined;
4) systems for collecting and processing information are being made significantly more complex, and sampling analysis of information is becoming more widespread.
5) a great deal of attention is being devoted to the implementation of the external design of apparatuses with the aim of increasing the ease with which they can be used.

In contemporary "artificial kidney" apparatuses meant to be used for extra-renal purification of blood by the method of hemodialysis, deaerated dialysis solutions (dialysate) of a prescribed composition and temperature can be automatically prepared, blood and dialysate can be moved through the dialyzer at prescribed rates, and the operating conditions can be controlled automatically.

In the apparatuses, the following functions are automatically controlled: the pressure on the input and the output of the perfusion pump; the level of blood in the air trap; the flow rate, temperature, and conductance of dialysate; and the leakage of blood into the dialysate.

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All these types of controls are designed to eliminate the possible occurrence of dangerous complications associated with a disturbance of the prescribed method of operating the apparatus or with a failure of its individual functional blocks.

To increase the safety of these apparatuses, several types of controls are duplicated. The control for the level of blood in the air trap is supplemented in the A 2008 C apparatus of the MTC firm (GFR) with a control for entrapped air bubbles located in the main line past where it leaves the air trap.

In addition, in contemporary "artificial kidney" apparatuses, the amount of information supplied the operator is still insufficient, and this situation is being more deeply realized by the developers of these apparatuses. To increase the speed of extra-renal purification, to decrease the expense, and simultaneously to guarantee safety, it is necessary to optimize the task set for the operating conditions of the "artificial kidney" apparatus, and at the same time to exclude the danger as much as possible that the apparatus may perform commands of the operator that are physiologically anomalous.

To accomplish this, first and foremost the operator must be provided with the parameters characterizing the normalizing action of the extra-renal purification of blood on the human organism. Such parameters include the dialysis time, the rate of blood flow, the rate of ultrafiltration, and the ultrafiltrate volume.

The greatest progress has been achieved in the sphere of automating the control of ultrafiltration. Methods presupposing the automatic collection of the necessary information, its automatic processing, and the subsequent visualization of the results through the use of numbered illuminated dials have replaced calculation methods to determine the rate of ultrafiltration, which were based on the collection of data by the operator about the transmembrane pressure in the dialyzer and on the processing of these data by hand.

The automatic control of the method of ultrafiltration has been put into effect in the majority of apparatuses represented at the exhibition. In the YG 130017 apparatus of the "I. Jeansolan S. A." firm (France), in the A 2008 C apparatus of the MTC firm (GFR), and in the "Siratron TM" apparatus of the "**Cordis** Dow" firm (USA) an isovolumetric method of control was used. In the 7200 apparatus of the "Drake-Willock" firm (USA), the parameters characterizing the method of ultrafiltration are determined in a computer onto whose input are fed signals about the pressures of blood and dialysate on the input and output of the dialyzer, as well as data about the type of dialyzer used.

The calculation method performed both manually and automatically is based on a number of assumptions regarding, for example, the law of distribution of pressures in the dialyzer, the determined conductivity for water of the dialyzer membrane, and the hypotheses about the uniform distribution of blood along the membrane surface, and about the determined magnitude of its effective surface area. The existence of these assumptions decreases the reliability of information regarding the operating conditions of ultrafiltration.

The direct control of ultrafiltration by the isovolumetric method is more promising. Here the volumes of prepared and expended dialysate are equalized automatically, and the excess fluid (dialysate) is measured by a specialized device.

Information regarding the rate of blood flow is very important to the process of obtaining the desired clinical effect of extra-renal purification.

In foreign "artificial kidney" apparatuses, roller type perfusion pumps are used exclusively. The output of these pumps depends on the speed of rotation of the drive shaft, as well as on parameters characterizing the kinematics of the pump and on the tubing used in the pump — its degree of compression. Therefore, when controlling the output of a roller type pump on the basis of information about the speed of rotation of the drive shaft, it is necessary to use assumptions which materially influence the accuracy of control. As a result, in not one of the apparatuses in which the flow rate of blood is controlled, is the degree of error of this control guaranteed.

The use of perfusion pumps of the roller type leads not only to an undetermined degree of error in the control of blood flow, but also to an amplification of the control of pressures at the input and output of the perfusion system; to guarantee that the system is sterile, it is necessary to use special dividing chambers, which separate the blood conducting connecting lines from the controlling device.

A trend among foreign apparatuses towards the full evaluation of parameters characterizing the normalizing action of the "artificial kidney" apparatus is most marked in the "Siratron TM" apparatus, in which the dialysis time is controlled, as well as the rate of ultrafiltration, and the ultrafiltrate volume. A very interesting innovation in this same apparatus is the automatic discontinuation of dialysis after a prescribed value for the ultrafiltrate volume has been achieved. The rate of ultrafiltration in this apparatus is stabilized at a prescribed level.

The automation of systems designed to meter out concentrate and water during the preparation of dialysate is achieved in foreign apparatuses basically through the use of plunger dosimeters of liquid agents. To prepare these dosimeters, one has to guarantee high accuracy for the interlocking dimensions of the plungers, and also one has to tighten the requirements that the materials used be resistant to wear. In addition, the specifications are raised regarding the degree to which piped water is purified of mechanical impurities, and regarding the minimal acceptable pressure of the piped water system. The magnitude of this pressure is 80 to 150 kPa.

Apparatuses in which bicarbonate is used to prepare the dialysate are receiving greater and greater recognition. Such apparatuses have two dosimeters for concentrate, one of which is used to meter out bicarbonate.

To make it possible to perform one-needle dialysis, the AK-10 apparatus of the "Gambro" firm (Sweden), the A 2008 C apparatus of the MTC firm (GFR), and the "Khiradis A" apparatus (Czechoslovakian SSR) are equipped with corresponding switching mechanisms.

Control of the leakage of blood is accomplished by determining the transparency of dialysate using a photoelectric method, which necessitates the initial adjustment of the control device before dialysis, and necessitates special sterile cleansing of this device after dialysis. The use of photoelectric devices complicates servicing the apparatuses and presents the danger that personnel may become infected during sterile cleansing of them.

Significant progress has been achieved in assimilating new methods of extra-renal purification -- ultradiffusion and hemofiltration.

At the exhibition, specialized apparatuses of the "Gambro" firm "Sweden) and of the "Fresenius" firm (GFR) were presented which were designed to be used for ultradiffusion and hemofiltration. From a technical point of view to bring these apparatuses for ultradiffusion into existence meant that they had to be able to perform dosimetry of ultrafiltrate and thermal stabilization of blood. In apparatuses for hemofiltration, besides solving these problems, one also has to solve the problem of how to dosimetrically replace ultrafiltrate with a sterile physiologic solution injection into the blood.

The devices for mass exchange hemodialysis exhibited at the exhibition were represented by disposable laminated and capillary dialyzers, which were characterized by values for indices of clinical effect (clearance and ultrafiltration rate) and by values for the filling volume of the blood conducting cavity which practically coincided. These dialyzers differ in the weight and dimensions. With equal indices of effectiveness, the weight of the laminated dialyzer and its average dimensions exceed the weight and dimensions of the corresponding capillary dialyzer by twofold. One should note that the last models of laminated dialyzers of the "Gambro" firm already approximate the capillary dialyzers in terms of their dimensions.

Devices for mass exchange hemofiltration (hemofilters), for example the FN101 and FN202 capillary hemofilters of the "Gambro" firm, are characterized by substantially greater values for the rate of ultrafiltration when compared with dialyzers. The ultrafiltration index of dialyzers with a membrane area of 1.0-1.2 m^2, is equal to 20-30 ml/h·kPa, while in the FN202 hemofilter, with a membrane area of 1.2 m^2, this index is equal 180 ml/h·kPa.

The results of an analysis of the means for extra-renal purification of blood exhibited at the "Public Health-80" international exhibition may prove useful in the design of domestic [USSR] models of analogous apparatus.