TECHNICAL ASPECTS OF SIMULATING CARDIOPLEGIA AND PERFUSION OF AN ISOLATED HEART

S. Sh. Kharnas, V. P. Plekhanov, L. S. Smirnov, and G. N. Yakunev

Prolonged stoppage of the heart during cardiosurgical intervention causes a decrease in the percentage of high energy phosphates, and alterations in the ultrastructure and the contraction capacity of cardiomyocytes. In the opinion of the majority of experimenters, these changes during cardioplegia are of a reversible character and upon expiration of a certain time after restoration of coronary blood flow to the myocardium, the energetics, structure and function are restored.

The need for objective study of the influence of various perfusion factors on the restoration of energetic metabolism and myocardial contraction capacity after cardioplegia stands at the forefront of research on the problem of developing an adequate experimental model. The well-known model of perfusion of the rat heart [1] correlates most closely with the implied goals. However, this model does not provide the complete set of conditions in which we find the heart during cardioplegia and restorative perfusion when cardiosurgical intervention occurs.

Fig. 1. Diagram of the setup for modelling cardioplegia and various conditions of restorative perfusion of the isolated heart. Explanation in text.
The goal of the present work has been to develop a model closer to a clinical prototype. To achieve this goal we designed and implemented an experimental apparatus for simulating cardioplegia and restorative perfusion of the isolated heart (Fig. 1). The apparatus consists of an oxygenator, a heat exchanger, a roller pump, an aortal reservoir, and a reservoir for perfusate. Also included are a diaphragm pump with a cardiosynchronized drive, an atrial reservoir, a system (for measured delivery of cardioplegic solutions) of two thermoregulated reservoirs connected through a throttle valve and a supplemental roller pump, and a hermetically sealed aortal reservoir connected with the output of the diaphragm pump. Other components of the apparatus are connected in the following arrangement: the thermoregulated reservoirs are connected with the supplemental roller pump; the reservoir for perfusate is connected through the primary roller pump and oxygenator with the diaphragm pump and through a throttle valve with the atrial reservoir; one of the thermoregulated reservoirs is connected via a stopcock with the aortal reservoir.

The setup also has a system for measured delivery of cardioplegic solutions, including reservoirs 1 and 2, the roller pump 3, throttle valve 4, and the thermoregulating device 5. In addition the setup includes a pneumatic drive 6, with a cardiosynchronizing unit; a membrane pump 7; a primary roller pump 8; an atrial reservoir 9; an aortal reservoir 10, with a manometer 11; throttle valves 12-14; a reservoir for perfusate 15; and an oxygenator 16. The isolated heart 17 is contained in a perfusion chamber 18, which is connected through a stopcock 19 with reservoir 1, and with the aortal reservoir 10. The thermoregulating device 20 regulates with perfusate temperature; reservoir 21 serves to collect perfusate returning from the heart (from its right chamber).

The modelling of cardioplegia is accomplished via a system for measured delivery of cardioplegic solutions, which is switched to the aorta of the isolated heart 17 by switching over the three-way stopcock 19. In this case reservoir 1 is connected with the aorta of the heart. The pressure and rate of delivery of cardioplegic solutions to the heart are set by the height of the column of solutions in reservoir 1 relative to the heart, and are maintained by constant recirculation of the cardioplegic solutions from reservoir 1 through the regulating valve 4 into reservoir 2 and back into reservoir 1 with the aid of the supplementary roller pump 3. The temperature of the cardioplegic solutions and the temperature in the perfusion chamber 18 are controlled by