Acute heart failure developing in patients after complicated operations on the heart and its vessels still accounts for many deaths in the immediate postoperative period. This necessitates a search for new and more effective ways of treating heart failure. One such method is an assisted circulation and, in particular, bypassing of the left heart [2]. By this method the work load on the myocardium is reduced and the arterial blood pressure (BP) is maintained at a level adequate for the needs of the body. There have been many investigations of effects of bypassing the left heart in man and animals, but the morphological aspect of this problem has not been adequately studied. There is virtually no information in the literature on processes taking place in the myocardium outside the zone of ischemia during the treatment of cardiogenic shock by an assisted circulation. Nevertheless, it is well known that compensation of heart failure is largely determined by the state of the structure and metabolism of these areas of heart muscle.

The object of this investigation was to study changes in the ultrastructure of areas of myocardium remote from the zone of ischemia during the development of cardiogenic shock and its treatment by bypassing the left ventricle.

**EXPERIMENTAL METHOD**

Twelve mongrel dogs weighing from 16 to 34 kg were used. The animals were anesthetized with barbiturates by the standard method. Artificial ventilation of the lungs was carried out with an RO-6 respirator through an endotracheal tube. Acute heart failure was reproduced by successive ligation of the descending branch of the left coronary artery. This led to a gradual decrease in the cardiac output (CO) and BP. After BP had fallen below 70 mm Hg, during continuous recording of parameters of the central hemodynamics, an artificial ventricle (AV) was connected to the arterial system between the left atrium and thoracic aorta. The AV was controlled by an AVK-5M apparatus, with pneumatic drive synchronized with the R wave of the ECG. In all experiments the work of the AV was synchronized with the animal's heart under counterpulsation conditions.

Material obtained by punch biopsy of the myocardium from the posterior wall of the left ventricle obtained at different stages of the experiment was used for the morphological investigations. The first biopsy was carried out at the time of development of cardiogenic shock immediately before the beginning of the bypass procedure, the second after operation of the assisted circulation for 2 h. The material was fixed in glutaraldehyde and in a buffered solution of OsO₄, dehydrated, and embedded in a mixture of Epon with Araldite. Sections were cut on the LKB-8800 Ultratome, stained with uranyl acetate and lead citrate, and examined in the IEM-100B electron microscope. A stereologic method of quantitative analysis was used to study the myocardium [6, 8]; mitochondria of cardiomyocytes were investigated. The surface area of the outer membrane of the mitochondria, the surface area of their cristae, and the relative volume of the mitochondria were determined. These parameters are volume fractions of the various structures in 1 μ³ of sarcoplasm of the cardiomyocytes. The numeri-
TABLE 1. Central Hemodynamics after Bypassing of Left Ventricle in Animals with Cardiogenic Shock

<table>
<thead>
<tr>
<th>Parameter of central hemodynamics</th>
<th>Intact heart</th>
<th>Cardiogenic shock</th>
<th>Bypass</th>
<th>After discontinuation of bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal systolic pressure, mm Hg</td>
<td>125 ± 8</td>
<td>61 ± 6</td>
<td>52 ± 5</td>
<td>76 ± 7</td>
</tr>
<tr>
<td>Maximal diastolic pressure, mm Hg</td>
<td>80 ± 5</td>
<td>40 ± 7</td>
<td>119 ± 9</td>
<td>50 ± 6</td>
</tr>
<tr>
<td>Mean intra-aortic pressure, mm Hg</td>
<td>86 ± 7</td>
<td>43 ± 6</td>
<td>74 ± 9</td>
<td>58 ± 5</td>
</tr>
<tr>
<td>CO, ml/min</td>
<td>2227 ± 148</td>
<td>1201 ± 30</td>
<td>761 ± 18</td>
<td>1630 ± 28</td>
</tr>
<tr>
<td>Work of the heart, kg·m/min</td>
<td>3.78</td>
<td>0.96</td>
<td>0.6</td>
<td>1.48</td>
</tr>
</tbody>
</table>

Fig. 1. Electron-micrograph of myocardium at time of development of cardiogenic shock (a) and 2 h after commencement of bypass (b): a) perinuclear edema, numerous evaginations of sarcolemma, disappearance of glycogen granules; b) disappearance of intracellular edema, outlines of nucleus smoothed, abundance of glycogen granules and secondary lysosomes in perinuclear space. 12,000 x.