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EXPERIMENTAL OPERATIONS ON THE ORIFICES OF THE HEART*

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IN the course of experiments made in 1913 and 1914 an attempt was made to develop technics by means of which plastic operations on the pulmonary and the aortic orifices of the heart could be performed. As it is the object of these operations that they be ultimately applied to human surgery, it was primarily necessary to accumulate about the operative procedure a number of factors of safety. It is not sufficient that a plastic operation be possible in order to be practicable. It must also be not dangerous. An attempt was therefore made, not only to perform plastic operations on the orifices of the heart, but to perform these operations without danger to the animal.

The animals were etherized according to the Meltzer-Auer method, and the thoracic cavity was opened under precautions precluding the occurrence of pleurisy. When the operative field had been walled off with silk and cotton knotted compresses, the pericardium was opened and the heart exposed. Then, according to the operation to be performed, the circulation of the heart was arrested and the pulmonary or aortic orifices were exposed and opened. In order to ensure the safety of this stage of the operation a number of details of technic had to be observed.

1. The arresting of the circulation of the heart has already been performed in many different ways by various experimenters. We ourselves have used all known methods of stopping the circulation through the heart. Finally we adopted the method of the clamping in mass of the pedicle of the heart by means of a large soft-jawed forceps. The heart was not taken out of the pericardium, but the incision of the pericardium was large enough to permit of the easy introduction of

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one of the jaws of the forceps under the pedicle. The forceps was a Doyen forceps, the jaws of which were covered with rubber. One of the jaws was introduced into the pericardium under the pedicle and directed from the right to the left side by the index finger of the operator. Before clamping, the position of the forceps was carefully examined. The handling of the forceps and of the pedicle was always very gentle. Care was taken not to produce any compression of the veins before the time of the clamping. It was important to allow the heart to be in a normal condition before clamping the pedicle. This result was obtained by over-ventilating the blood, which was easily done on account of the employment of the Meltzer-Auer method. It was noticed that if the heart was clamped before it was in excellent condition the interruption of the circulation could not be as innocuous as when the heart was filled with well-oxygenated blood. The advantage of using the Meltzer-Auer method in this operation is that it permits of an acceleration of the oxygenation of the blood at will. When everything was ready for the performance of the operation the forceps was rapidly clamped and, without a second being wasted, the heart or the vessel was opened and the operation was started.

When the above-mentioned precautions were taken, it was possible to clamp the pedicle of the heart for two minutes and a half or three minutes without any subsequent trouble. As soon as the clamp was removed the heart resumed its pulsation and after a very short time the pulsations were again normal. In no case was there any need of massaging the heart when the interruption of the circulation did not exceed two and one-half minutes. This probably allows of a considerable margin of safety and it would doubtless be possible to prolong the operation a little without danger to the animals. But two and one-half minutes appears to be sufficient time for the performance of several operations on the valves.

The above technic is apparently somewhat crude, but experience has shown that it was simpler than the separate clamping of the arterial and venous pedicles, and that it required less handling of the heart, which is an important consideration. Moreover, the traumatism of the anatomical structure of the pedicle of the heart is slight, on account of the large quantity of tissue which is taken up between the jaws of the forceps and which renders their action less rough.

2. The aortic and pulmonary orifices were exposed by means of incisions made through the anterior wall of the arteries at the level or a little above their junction with the heart. The incision was made with scissors of unequal blades, one of the blades being sharp and

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longer than the other. This permitted of the perforation of the wall of the artery or heart before cutting. The location of the incision was exactly determined. For the pulmonary artery the incision was made on the left side of the artery at a point corresponding with the junction of the anterior and left sigmoid valves. Several times the valves were exposed by an incision made only on the pulmonary artery. Generally they were exposed by an incision of about 4 cm. made half on the pulmonary artery and half on the ventricle of the heart. In that region the branches of the coronary artery are small and can be cut without danger. The exposure of the aortic valves was made through an incision located on the right side of the aorta between the mouth of the right and the left coronary arteries, generally directly above the middle of the right valve. Great care was taken not to injure the mouth or the branches of the coronary arteries.

3. The opening of the ventricles or of the pulmonary artery and the aorta is always followed by entrance of air into the heart. When the pulmonary artery and the right ventricle were opened, no special care was taken to empty the heart of air at the conclusion of the operation. The quantity of air was probably very small. No accidents have been observed after the entrance of air into the right heart and the lungs. But the introduction of air into the aorta and the left ventricle was very dangerous. When the operation was completed and the circulation re-established the air emboli were sent through the coronary vessels, and this caused fibrillary contractions of the heart and consequent death. On several occasions it was possible to see the air emboli in the coronary arteries. It was, therefore, necessary for the safety of the operation to eliminate the possibility of such a complication. This could be done by aspirating the air contained in the heart by means of a large needle or cannula introduced into the ventricle or into the aorta and connected with a vacuum apparatus. This operation was performed rapidly just before the removal of the clamp and the re-establishment of the circulation.

Several kinds of operations were performed. The sigmoid valves of the aorta were exposed and cauterized. The pulmonary orifice was cut after the wall had been patched with a piece of vessel preserved in cold storage. These three operations were performed with the purpose of ascertaining whether operations such as should be made in cases of inflammation, stenosis, or dilatation of the orifices would be possible.

1. *Opening of the Aorta and Cauterization of the Sigmoid Valves.*—After the artery was exposed and the pedicle clamped the aorta was opened by an incision made with the scissors, just

above the sigmoid valves. A large quantity of blood immediately escaped. Next, the incision was kept open by two forceps. The blood in the vessel was washed and sponged. The valves could easily be seen and they were cauterized with a thermocautery. The aortic incision was next closed by means of a continuous suture with Chinese silk No. 1 sterilized in vaseline. Through the line of the suture a curved cannula in communication with a vacuum apparatus was introduced into the aorta and the air contained in the left heart was aspirated. Then the clamp was removed after the circulation had been interrupted for about three minutes. After the occurrence and the treatment of air emboli of the right coronary artery, the heart resumed its normal pulsation, the pericardium was closed, and the operation was completed in the ordinary manner.

2. *Patching of the Pulmonary Artery and Arterial Cone.*—This operation was made with the purpose of ascertaining whether the pulmonary orifice could be made larger. The operation consisted in suturing on to the surface of the pulmonary artery a patch of vein preserved in cold storage and in cutting the edge of the orifice underneath the patch. The operation was made in the following way: A piece of vena cava or of any other vein, preserved in cold storage, was cut into the shape of a rectangular flap about 2.5 cm. by 2 cm. This flap was put on the anterior part of the pulmonary artery in such a way that its middle corresponded about to the pulmonary orifice, the lower part being on the surface of the ventricular wall. Then the two lateral sides and the upper sides were fixed to the surface of the heart and the pulmonary artery by means of a continuous suture. The longer blade of the scissors was introduced underneath the lower side of the flap and the sharp point was introduced into the lumen of the pulmonary orifice. Then the wall was cut, and dark blood escaped between the surface of the heart and the lower part of the flap; but the hemorrhage was immediately controlled by the index finger of the operator which compressed the flap down on the wound. The fourth side of the flap was next fixed to the surface of the heart by a continuous suture. The flap immediately appeared distended by dark blood and it was assumed that in case of stenosis of the pulmonary orifice this operation would permit of a dilatation of that orifice. The operation was performed without stopping the circulation of the heart. The operation would be rendered easier by clamping the pedicle of the heart for a very short time. Although this is a more dangerous procedure, it is probable that it would simplify the operation.

3. *Suture of the Sigmoid Valves of the Pulmonary Artery.*—After the pedicle of the heart was clamped the pulmonary artery

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and the left ventricle were opened by means of an incision about 4 cm. long. The incisions were located on the left side of the pulmonary artery. Half of the incision was on the artery and half on the ventricle. It passed at about the union of the left and anterior sigmoid valve. Dark blood was immediately expelled from the heart and after the heart was emptied very little blood remained on the operating field. The edges of the wound were retracted by two forceps. The sigmoid valves could easily be seen and handled with the fingers or with the forceps. In one case the posterior parts of the left and the right sigmoid valves were united by a stitch at about 3 mm. distance from their insertion to the wall. In another case the right sigmoid valve was cut in the middle part with the scissors and the edges of the wound were united by a stitch made with a straight needle No. 16 and fine silk sterilized in vaseline. When the operation was completed the edges of the incision were united by a continuous suture made with straight needles and China silk No. 1. Then the clamp was removed and the circulation re-established. The duration of the interruption of the circulation was a little more or less than two and one-half minutes. As soon as the clamp was removed and without the necessity of any massage, the heart resumed its pulsations. After a short while the pulsations were normal and the operation could be completed by the suture of the pericardium and the suture of the wall, according to our ordinary methods.

The results of these operations must be considered from two stand-points: (1) the dangers involved to the life of the animal by these operations, and (2) the general and local results of the operations.

When the technic which has been described above is carefully followed out, the operation is of little danger to the life of the animal. In eight cases with the collaboration of Dr. Tuffier, we performed the patching and the incision of the pulmonary orifice. One dog died of pericarditis after a few days. This was probably due to the fact that the heart was handled without rubber gloves. Another dog died on the operating table of fibrillary contractions of the heart. This was produced by an error of technic. The flap had been put on the right side of the pulmonary artery instead of the left side, and it was found that some stitches had interrupted the circulation in a comparatively large branch of the coronary artery. In six other cases the animals sustained no shock. They remained in very good health, and are still normal six months after the operation. In several of these animals the incision of the orifice was too short. In other cases the flap was

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too narrow and did not allow for the dilatation of the orifice. The result was that no murmur could be heard by auscultation. Nevertheless, in two cases a marked diastolic murmur was present a few weeks after the operation. It was found that in these dogs the murmur had disappeared after five months. It must be noted also that these remote results demonstrated that a piece of vein put on the pulmonary artery in contact on the one side with dark blood, on the other with the pericardium, that is in an unfavorable condition of nutrition, did not undergo necrosis.

The results of the suture of the sigmoid valves were better. Three operations were performed. Although there was an interruption of the circulation of the heart by the clamping of the pedicle, and the heart and artery were widely opened, the condition of the animals remained perfect, both during the operation and afterwards. Not only did these three animals sustain no shock, but their condition at the end of the operation was exactly the same as after the mildest kind of operation. In the afternoon of the day of the operation they were entirely normal again, and to-day, that is 25 days after the operation, they are in excellent condition. The dog on which the section and the suture of the sigmoid valve was performed is an animal about eight years old. Nevertheless his general condition was not modified by the operation.

The purpose of these operations was to show how extensive a plastic operation on the heart can be made without danger to the life of the animal. The results demonstrate that many factors of safety have been placed in the technic. It will perhaps be possible to perform successfully more complicated operations than those we have described. These results are being published at the present time merely to show that plastic operations on the heart need not be dangerous. It is not impossible that some day surgeons will be able to cauterize valvular lesions or to repair them as we do to-day in our experimental operations.