

MORPHOLOGY AND PATHOMORPHOLOGY

MORPHOLOGICAL CHANGES IN THE HEART, LUNGS AND BRAIN AFTER EXPERIMENTAL CAVOPULMONARY ANASTOMOSIS

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Vascular anastomoses (the subclaviopulmonary of Blalock, the aortopulmonary of Potts and the cava-pulmonary of N. K. Galankin) are the most effective and easiest methods of treatment of a number of congenital heart lesions and are being used on an ever increasing scale in the clinics of the Soviet Union.

Of particular value for the clinician is the cavopulmonary anastomosis, which was suggested and developed in the A. V. Vishnevskii Institute of Surgery of the AMN SSSR.

The technique of the operation is as follows. A right-sided thoracotomy is performed with resection of the third rib. The superior vena cava and the right branch of the pulmonary artery are isolated. The latter is ligated at the point of its emergence from the pulmonary trunk, and is divided distally to the ligature. The superior vena cava is ligated distally to the azygos vein and is also divided distally to the ligature. The isolated peripheral ends of the superior vena cava and of the right pulmonary artery are joined to each other end-to-end by means of a Donetskii metal ring. As a result the flow of blood from the superior vena cava is shunted directly into the right pulmonary artery, by-passing the right atrium and right ventricle. In Fallot's tetralogy, because of the constricted outlet of the right ventricle, the volume of blood entering the lesser circulation is inadequate. The formation of a cavopulmonary anastomosis leads to an increase in the minute volume of the lesser circulation on account of blood entering from the superior vena cava.

The use of this operation in the clinic has yielded good immediate results (E. N. Meshalkin, A. A. Vishnevskii and N. K. Galankin). However there are as yet no clear ideas on the morphological changes arising in the body as a result of the formation of a cavopulmonary anastomosis.

The performance of the operation of cavopulmonary anastomosis is accompanied by a number of powerful and unaccustomed influences on the body — temporary clamping of the superior vena cava and shunting of the right pulmonary artery. As a result of the operation a considerable redistribution of the blood takes place, in consequence of which the filling of the right ventricle with blood is reduced by approximately 40% and the blood flow in the vessels of the right lung takes place at a much less pressure than normally. The aim of the investigation was to study the morphological changes in the brain, lungs and heart after the formation of a cavopulmonary anastomosis.

EXPERIMENTAL METHOD

Experiments were carried out on 21 adult dogs. After the formation of a cavopulmonary anastomosis they lived for periods from 3 hours to 5 months. An end-to-end anastomosis was formed between the peripheral ends of the superior vena cava and the right pulmonary artery in 13 dogs and an end-to-side anastomosis in 8 dogs.

TABLE

Summarized Results of the Experiments

Experiment No.	Type of anastomosis	Postoperative complications	Thrombosis of the anastomosis	Duration of survival after operation	Cause of death of the experimental animal
9	End-to-end	—	None	15 hours	killed
11	The same	Pleurisy and pneumonia	»	22 days	Pleurisy
12	» »	Pneumonia	»	8 days	Pneumonia
13	» »	Bilateral pneumothorax	»	3 hours	Bilateral pneumothorax
20	» »	Pleurisy	»	18 days	Killed
21	» »	»	»	75 »	Pleurisy
22	» »	»	»	5 »	»
23	» »	»	»	30 »	»
26	» »	Bilateral pneumothorax	»	3 hours	Bilateral pneumonia
27	» »	No complications	»		Killed at the end of the operation
29	» »	The same	»	3 days	Cause uncertain
30	» »	» »	»	5 months	Died from strangulation by the chain
32	» »	» »	»	36 days	Killed
34	Pleurisy, pericarditis	» »	»	24 hours	Died from strangulation by the chain
38	The same	Pleurisy, pericarditis	Mural thrombus	14 days	Thrombosis of the right atrium
40	» »	Bilateral pneumothorax	None	20 hours	Bilateral pneumothorax
41	» »	Pleurisy	Thrombosis of the right atrium	15 days	Pleurisy
42	» »	Pleurisy, pericarditis	None	28 »	Bilateral suppurative pleurisy
43	» »	No complications	»	10 hours	Killed
45	» »	The same	Mural thrombus of the anastomosis	35 hours	»
46	» »	Pleurisy	Mural thrombus	10 days	Pleurisy

At the time of formation of the end-to-end anastomosis the blood flow through the superior vena cava had to be completely interrupted for 30-40 minutes. When the anastomosis was formed end-to-side the superior vena cava was only partially occluded, so that the natural flow of blood along it was preserved. Only after the anastomosis was operating was the superior vena cava ligated proximally to the anastomosis, thereby directing the flow of blood from the superior vena cava to the pulmonary artery.

EXPERIMENTAL RESULTS

In the Table we give the summarized results of the experiments together with an indication of the complications and causes of death of the animals. As may be seen from these results, 8 dogs survived for up to 35 hours after the formation of the anastomosis (1st group), 6 dogs survived for 3 to 15 days (2nd group) and 7 dogs for 18 to 150 days (3rd group).

Histological examination of the heart, lungs and brain of the experimental animals was carried out. Fragments were excised from all parts of the lungs. All the divisions of the heart were examined: the anterior and posterior walls of the right and left ventricles, the interventricular septum, the right and left atria and the auricles of the right and left atria. For the study of the brain fragments were excised from its various divisions, enabling the cortex, basal ganglia and brain stem to be examined. The material was fixed in 10% neutral formalin solution. Sections were stained with hematoxylin-eosin, Scharlach red and by Nissl's method.

On histological examination of the lungs, irrespective of the length of time after operation and the method of formation of the anastomosis, well marked hyperemia was found. Vessels of all calibers were dilated and distended with blood. At early periods after operation (up to 28-36 days) foci of edema of the lungs were found on the side of anastomosis. Here and there the edema was more pronounced beneath the pleura than in the other parts of the lungs. Large foci of atelectasis and areas of emphysema were seen. Very large areas of pulmonary edema, with rupture of alveolar septa were found in association with the use of artificial respiration under increased pressure. In places whole "lakes" were formed as a result of rupture of the alveolar septa by edema fluid. In the small and large bronchi edema fluid was also present. In 7 animals a fibrinopurulent pleurisy developed, in places with signs of organization of the exudate. In these places the pleura was greatly thickened with calcareous deposits. Here and there in the lung tissue were seen large and confluent foci of hemorrhage. In some preparations the alveoli were continuously bathed in blood and distended with red blood cells.

In one dog a thrombus with commencing organization was found in the main pulmonary trunk. A noteworthy feature was the almost complete absence of shrinkage of the lung or signs of sclerosis and atrophy of the lung parenchyma even at late periods after operation.

On examination of the heart, in 4 dogs fibrinopurulent pericarditis was found, in places with organization of the exudate. The epicardium in these cases was infiltrated with segmented leucocytes, eosinophils and plasma cells. In these animals foci of deposition of tiny droplets or clouds of fat were seen in the cardiac muscle fibers in various regions of the heart, most commonly beneath the epicardium. No other changes were found in the heart after careful histological examination.

On histological examination of the brain well marked hyperemia of the vessels was found. In 3 dogs multiple or solitary foci of hemorrhage had appeared in the brain substance (in two of these dogs the cavopulmonary anastomosis was formed end-to-end and in one, end-to-side). At late periods after operation no hyperemia of the cerebral vessels was found.

As a result of the anastomosis between the superior vena cava and the pulmonary artery changes develop in the body soon after the operation — hyperemia of the vessels of the lesser circulation with the appearance of foci of hemorrhage and edema in the lungs and foci of hemorrhage in the substance of the brain.

The fibrinous pleurisy and pericarditis develop in consequence of the opening of the pleural and pericardial cavities and are not directly concerned with the operation of cavopulmonary anastomosis; they are complications of intrathoracic and intrapericardial procedures in general.

According to S. M. Smirnov, ligation of a main branch of the pulmonary artery is followed by cirrhosis of the lung, which shrinks to $\frac{2}{3}$ of its original volume. The operation of cavopulmonary anastomosis is also attended by ligation of a main branch of the right pulmonary artery. However, in contrast to simple ligation of the artery, in cavopulmonary anastomosis the flow of blood from the superior vena cava is directed into the peripheral end of the right pulmonary artery. Evidently as a result of this, pneumosclerosis does not develop. The absence of pneumosclerosis after the operation of cavopulmonary anastomosis, despite ligation of the pulmonary artery, is one of the advantages of this operation.

A serious complication of the operation of cavopulmonary anastomosis is the appearance of foci of hemorrhage in the brain substance. As a result of the prolonged clamping of the superior vena cava and the consequent sharp rise in pressure therein, foci of hemorrhage develop in the brain, morphologically similar to those produced by diapedesis. Hence the severe and acutely developing venous hyperemia of the brain, resulting from the prolonged clamping of the superior vena cava and the associated increase in pressure in that system may cause in some animals the development of hemorrhages in the brain substance by diapedesis. The prolonged clamping of the superior vena cava during the operation of cavopulmonary anastomosis also causes the development of multiple foci of hemorrhage in the skin of the head, face, neck and shoulder girdle, as shown by examination of the cadaver of a patient who died soon after the operation.

The mechanism of development and the causes of the appearance of foci of hemorrhage in the skin and the brain are the same. For this reason the appearance of foci of hemorrhage in the skin must be regarded by the doctor in charge of the patient during the postoperative period as a serious sign of the possible development of hemorrhages by diapedesis in the substance of the brain.

This question of the prevention of foci of hemorrhage in the brain after the operation of cavopulmonary anastomosis is of real and urgent importance in the clinic, as is confirmed by our morphological investigations.

Occlusion of the superior vena cava is accompanied by a reduction in the minute volume of the right heart by approximately 40%. The sharp reduction in the blood flow must apparently cause changes in the heart as a result of the rapid change in the usual hemodynamic conditions. Nevertheless neither dystrophic nor atrophic changes were found on careful histological examination of all the divisions of the heart, which is another advantage of the operation of cavopulmonary anastomosis.

The complications of cavopulmonary anastomosis are in part a matter of the great, important and as yet incompletely solved problem of operative trauma.

To reduce the risks of the operation of cavopulmonary anastomosis it is essential to improve the operative technique. In the first place ways must be found of preventing the complications arising during occlusion of the superior vena cava.

SUMMARY

The authors studied the morphological changes occurring in the heart, lungs and brain after placing the cavopulmonary anastomosis. Experiments performed on 21 dogs established that prolonged occlusion of the superior vena cava during placing the cavopulmonary anastomosis may cause the development of diapedetic hemorrhages in the brain substance. The placing of cavopulmonary anastomosis may cause the development of fibrinous pleurisy and pericarditis. Cavopulmonary anastomosis is not connected with the development of pneumosclerosis, notwithstanding the ligature of the right pulmonary artery. No morphological changes are caused in the heart as a result of disengaging the superior vena cava from the right auricle. It is necessary to improve the technique of this surgical procedure to minimize its danger. It is of importance to reduce the time of occlusion of the superior vena cava during the operation.