Surgical Closure of the Patent Ductus Arteriosus*

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The patent ductus arteriosus was first described by Galen. No thought was given to the surgical treatment of patients with persistently patent ducti until 1907, when Munro described a technique for their ligation. It was not until twenty-one years later that Gross of Boston successfully ligated a patent ductus arteriosus for the first time.

Since the epochal operation by Gross increased attention has been given to the surgical treatment of patent ductus arteriosus in America. The field has been further extended from that of a noninfected case to include surgical cure of cases of subacute "Streptococcus Viridans" endarteritis associated with patent ductus arteriosus. More recently additional cases of patent ductus arteriosus with other congenital heart disturbances which have been successfully treated surgically have been reported.

In fetal life the ductus arteriosus serves the important function of shunting blood from the pulmonic artery to the aorta thus by-passing the lungs. When the child is born, the lungs expand and the ductus normally closes. The blood in the pulmonary artery then passes through the lungs to be aerated. If the ductus fails to close the patient then possesses a persistently patent ductus arteriosus which is essentially an arteriovenous aneurysm.

There is considerable difference of opinion as to the time in which a patent ductus arteriosus closes under normal conditions. According to Christi in a study of routine autopsy specimens from infants, at eight months only 2 per cent of the ducts remained open. Gross sets an arbitrary time limit of one year, believing that an open ductus after that time should be regarded as being abnormal. In discussing the etiology of a patent ductus arteriosus, Gross points out three interesting possibilities to be considered. Of these, the most important is the position and direction of the vessel. The ductus usually enters the aorta at an acute angle, and as the acuteness of the angle decreases, the ductus becomes more and more exposed to intra-aortic pressure. If the angle becomes a right, or even an obtuse angle, the force of intra-aortic pressure

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can readily be exerted to maintain patency of the lumen of the ductus. Gross has repeatedly observed this deviation from the usual acute angle in his operative experiences. The second possibility is a defect in the elastic fiber of the media, decreasing the contractibility of the ductus. A third possibility is a deficient neurovascular tonus. The discussion of these possibilities does not apply to cases in which another congenital defect acts to maintain an open ductus arteriosus as a compensatory mechanism.

Maude Abbott, in a series of 1000 autopsies, has shown that the patent ductus arteriosus may be accompanied by other congenital abnormalities; consequently, these pathological combinations must be taken into consideration in the differential diagnosis of patent ductus arteriosus. On the other hand, it must be remembered that a patent ductus arteriosus can, and does, exist as a single cardiac anomaly; and in most such cases presents sufficient hazards that operation is not only a justifiable procedure, but is definitely indicated.

Eppinger and Burwell, with Gross, studied the effects of the patent ductus on the heart and circulation before and after ligation of the ductus. It was observed that the blood flow is from the aorta to the pulmonary artery in the presence of a patent ductus. No flow takes place from the pulmonary artery to the aorta; hence, the patient is not cyanotic. Studies clearly show that a tremendous strain in the presence of a patent ductus arteriosus is imposed upon the heart which explains the frequent occurrence of cardiac decompensation and circulatory failure among patients having this lesion. This may also cause a diminution of the blood flow to the peripheral vascular system.

The hazards of a patent ductus arteriosus are further demonstrated by studies of the life expectancy of such patients. In ninety-two cases cited by Maude Abbott, the mean age of death was twenty-four years. However, the mean age in her series is somewhat confusing since twenty of the patients died in infancy. A review of eighty cases, in which all patients were over three years of age at the time of death and each diagnosis was proved by autopsy, was made by Jones, Dolley and Bullock. They presented the following statistics:

By fourteen years of age, 14 per cent died of their heart lesion.
By thirty years, 50 per cent died of their heart lesion.
By forty-one years, 71 per cent died of their heart lesion.

Both Gross and Maude Abbott have pointed out the alarming fact that the incidence of subacute endocarditis is in the neighborhood of 25 per cent. Aside from cardiac decompensation,
other possible complications are bacterial endocarditis or endarteritis, aneurysmal dilatation of the ductus, rupture of the ductus, and possible retrograde thrombosis with release of emboli to various parts of the body. In one of our cases an aneurysm of the pulmonary artery associated with a patent ductus arteriosus was encountered. Thus, it is apparent the surgeon must approach this surgical entity with the realization that he may encounter numerous abnormalities other than a patent ductus arteriosus alone.

The patent ductus arteriosus is seldom recognized during the first few years of life. Usually, however, when the child progresses to the period of physical activities, symptoms of dyspnea, increased heart rate, or a pounding heart may develop. As the age of the patient advances, shortness of breath and pounding of the heart on slight exertion is a rather persistent complaint and may be the first symptom to lead to the recognition of a patent ductus. It is important to realize that cyanosis is not present except as a terminal symptom of impending death. The patient may present evidence of being undernourished, but if a ductus remains patent until early adult life, the patient is apt to become more normally developed. Perhaps the most determinative factor in diagnosis is the so-called “machine” murmur to be found at the pulmonic area in the second or third interspace to the left of the sternum. This murmur is transmitted to the left axilla and can be heard, in many instances, toward the back. Although a thrill does not exist in every case, it is usually present, and its existence is to be considered one of the chief diagnostic points. In one of our cases, no thrill could be felt through the chest wall, but it was readily palpable when the thorax had been opened. Patients complain of a humming sound in the chest and an annoying thumping in the ears upon lying down. There are some extreme cases in which the murmur may be heard by individuals standing near the patient. The mother of one of our patients stated that the murmur of her child was so pronounced it was audible to her when she slept with the child. The blood pressure is another sign of importance. The systolic level is normal or slightly lowered, while the diastolic level is greatly decreased. The Corrigan pulse and the pistol shot sounds may be detected in the peripheral arteries when the pulse pressure is high. Percussion shows a heart of normal or slightly increased size. The electrocardiogram, as a rule, is not diagnostic.

Roentgenological studies reveal a large pulmonary conus, and may further reveal congestion of the opposite lung in the region of the hilus, although neither of these signs is persistent during early childhood. The x-ray findings serve as important contributory evidence, rather than as a basis for diagnosis.
Selection of Cases

Gross\textsuperscript{15} has stated that the various hazards are sufficiently serious and appear frequently enough to make surgical closure of a patent ductus arteriosus advisable, provided this can be accomplished with a reasonably low mortality rate. There are, of course, some cases where contra-indications to operation exist. Touroff\textsuperscript{15} mentions two absolute operative contra-indications. First, in those cases where there is incontrovertible evidence that the open ductus is present as a compensatory mechanism for some other co-existing congenital cardiovascular anomaly, ductal ligation quickly leads to circulatory embarrassment and death. Second, where there is strong evidence that vegetations already have spread to the endocardium, aorta, or to the mitral or aortic valves, ductal ligation is of no value for the reason that new lesions continue to feed infective material directly into the peripheral blood stream. However, he emphasized that the presence of an infection of long duration does not necessarily constitute a contra-indication to operation unless vegetations already have spread to the above mentioned areas.

Operation

The operative technique of most surgeons is similar to that employed by Gross\textsuperscript{2,7,14,17} except in certain details. The incision we employ begins at the lateral border of the sternum and extends laterally for a distance of five to six inches over the second interspace. Munro,\textsuperscript{19} in 1907, first suggested the possibility of ligating a patent ductus arteriosus through a sternal approach. Although Gross cuts the second and third cartilages to obtain better exposure, we have found this unnecessary. It is possible to obtain adequate exposure without cutting the rib structure by placing a rib spreader between the second and third ribs. Certain anatomical relations are to be observed in identifying the duct. A sentinel lymph node lies at the superior border of the base of the lung, and from the lymph node the incision is extended upward through the mediastinal pleura. The aorta, which has a tough wall, can be easily and safely identified by rather firm dissection. In contrast to the aorta, it is well to remember, the ductus has a thin wall and must be freed with care. In fact, several cases have been reported where the ductus was torn during the operation with fatal results.\textsuperscript{10,19,20} The vagus nerve is identified and traced to its recurrent laryngeal branch which courses medially under the ductus. The area of maximum thrill which lies directly over the ductus is then sought by palpation with the tip of the index finger. By following these steps, it is possible to quickly and confidently identify the ductus arteriosus except in cases in which
other anomalies exist. Such an exceptional case came under our observation in the form of a patent ductus arteriosus associated with a large aneurysm of the pulmonary artery. In this patient, either because of the expansile pressure of the aneurysm or because of the congenital anomaly, the pericardium, instead of being attached to the pulmonary artery as is normally the case, was attached to the inferior surface of the aorta; thus making it necessary to open the pericardium in order to expose the ductus.

The danger of cutting through the ductus, if the ligature is tied too tightly, is pointed out. Mont Reid advocated the umbilical tape ligature of woven silk 5/32 inch in breadth. Gross has supplemented the use of a ligature of cellophane placed over the silk ligatures. Herman Pearse of Rochester, New York, has found through experimental work that cellophane increases the proliferation of fibrous tissue. Sclerosing fluid injected into a short segment of the ductus isolated by two ligatures has been employed by Gross. More recently Gross has reported a series of fourteen cases in which complete surgical division of the patent ductus arteriosus was successfully achieved. Touroff has stated that in his experience he had found ductal ligation to be similarly effective to ductal division. Our experience with ligation has been similar to that of Touroff. We have had excellent results and no complications by tightly, doubly ligating the ductus with No. 8 braided silk.

Following the ligation of the duct, the machine murmur is usually converted to the sound of a normal heart. However, some cases have been reported in which a residual murmur can be heard. There is an immediate cessation of the thrill, and the violent action of the heart is toned down; thus indicating the heart was carrying an additional load in the presence of a patent ductus arteriosus. A rapid improvement in weight and good health is noticeable in the undernourished and underdeveloped patient. The diastolic blood pressure, which is low in these cases is immediately elevated. Dramatic results may be obtained in cases of subacute Staphylococcus endarteritis associated with a patent ductus arteriosus. Since the mortality rate of approximately 100 per cent for untreated cases with associated endarteritis has been reduced to less than 50 per cent by ligation, as pointed out by Burch, it would seem that surgical treatment should be urged in such cases. In a successful case reported previously, the patient had been confined to her bed with an elevation of temperature and a repeatedly positive blood culture. A blood specimen taken twenty-two minutes after the duct was ligated showed a negative culture. Other similar cases have been reported by Touroff, Harrington, and Shapiro and Keys. No clear explanation has been advanced as to why
the blood culture taken shortly after the operation was sterile.

Aside from the usual complications of any thoracotomy, such as sepsis, pneumonia, and post-operative thrombosis, there are others which may occur during the operation for ligation of a patent ductus arteriosus:

1) Inability to identify the duct;
2) Injury to the duct during ligation;
3) Incomplete occlusion or perforation of the ductus by ligature;
4) Injury to the recurrent laryngeal nerve.

In one of our cases in which the ductus lay within the pericardium, the recurrent laryngeal nerve was injured during the rather extensive dissection which was carried out in an effort to locate the ductus. The patient developed a hoarse voice post-operatively, but within five weeks her voice had become normal. During the first thirty-six hours post-operatively the patient is likely to develop sufficient pleural effusion to produce a certain degree of respiratory embarrassment. This is easily relieved by the use of the aspirating needle.

Although the length of time since most of these operations have been performed is too short to offer conclusive evidence as to the degree of permanence of the cure, the results are sufficiently beneficial to warrant continued interest in surgical treatment of such cases.

SUMMARY

The function of the ductus arteriosus before birth is explained, and the reasons for its remaining patent after birth are given.

Symptoms and diagnostic points are discussed, and the operative technique and results of the ligation of a patent ductus arteriosus are described.

Statistics of the cause of death of untreated cases are presented together with numerous abnormalities and complications which may be encountered during the ligation of a patent duct.

RESUMEN

Se explica la función antenatal del ductus arteriosus, y se presenta las razones por las cuales puede permanecer abierto después del nacimiento.

Se discute síntomas y puntos en el diagnóstico, y se describe la técnica operatoria y los resultados de la ligación del ductus arteriosus abierto.

Se presenta datos estadísticos relativos a la causa de muerte en casos no tratados, así como numerosas anomalías y complicaciones que se puede encontrar durante la ligación de un ductus abierto.
REFERENCES

1. Franklin, K. J.: Cited by Burch. (23).
Discussion

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Doctor Nixon's paper on patent ductus arteriosus is both timely and interesting. It is especially timely, I think, because it is a subject on which a great deal of thought and consideration is being given right now. In the past, to most of us, patent ductus arteriosus just fell into that general classification of congenital heart, and it was only of interest when it came to the post-mortem table. Now, we know that it is not enough to make a diagnosis of congenital heart and leave it at that. We should go much further in an attempt to make an accurate differential diagnosis because in the case of patent ductus arteriosus we may have something definite and worth-while to offer the individual, thus changing a bad prognosis as to longevity to a much better prospect of living a normal life.

However, let me stress right here the importance of making an accurate diagnosis, because even in the best clinics post-mortems have shown a rather high percentage of error. Dr. M. J. Shapiro, Clinical Director of Children's Heart Hospital and Clinic of Minneapolis, Minnesota, suggests nine steps which I think are worth mentioning here:

1. History of heart disease from birth or early childhood.
2. No cyanosis or clubbing of the fingers.
3. Stunting of growth, in a small percentage of cases.
4. Probable thrill over the pulmonic area.
5. Characteristic machinery murmur, or the humming top murmur, over the second left interspace.
6. Increased pulse pressure.
7. Normal electrocardiogram.
8. Probably enlarged heart.

In these last three points, of course, an expert roentgenologist experienced in chest diagnoses, particularly of children, would be of great help.

So, I feel that Dr. Nixon's paper is of special interest because it emphasizes our duty as chest men to try to make an exact diagnosis in congenital heart disease, since we know from Dr. Maude Abbott's work on congenital cardiac disease that there may be more than one defect present. Therefore, when a patent ductus arteriosus is found to be the condition and we have carefully eliminated, to the best of our ability, other congenital defects, then, I feel, these cases should have the benefit of ligation by a good thoracic surgeon.