ANESTHESIA IN SURGERY OF THE PATENT
DUCTUS ARTERIOSUS* †

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The purpose of this paper is to report our anesthetic experiences in the surgical ligation of the patent ductus arteriosus.

Until a few years ago, the patient with a patent ductus botalli (ductus arteriosus) faced a somewhat grim future. True, some of the patients lived long and active lives, but they risked the following complications (1): physical retardation; cardiac failure; streptococcus viridans endarteritis (or endocarditis), and rarer complications, as rupture of the ductus, embolism from thrombosis of the ductus and aneurysmal dilatation of the ductus.

Munro (2), in 1907, suggested the surgical closure of the patent ductus; this was first attempted by Strieder (3) in 1938 without success. In 1939, Gross (4) reported the first successful ligation of a ductus, and in 1940, Touroff (5) described the first cure of a streptococcus viridans endarteritis by surgical ligation of a patent ductus arteriosus.

THE PATIENT

Thirty patients were operated on at Mount Sinai Hospital for patent ductus arteriosus. Six were males and 24 were females. Fourteen of the patients were between 5 and 10 years of age, 7 between 11 and 20 years and 9 were over 21 years of age. The oldest patient was 63 years of age. Ten patients had endarteritis of the ductus. The 20 patients who did not have complications were in good physical condition, although they were undersized and puny as a group. All had good cardiac reserve with no evidence of failure. The status of the patients with endarteritis was not as favorable; as a group they presented the picture of moderate debility with anemia—all the evidence of a low-grade, chronic sepsis. Only one patient had heart failure with dyspnea and orthopnea of three months' duration. Cyanosis was absent in all 30 cases.

The patients showed the typical auscultatory findings of a patent ductus arteriosus, a loud machinery-like murmur, heard both in systole

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and diastole at the left sternal border over the third and fourth intercostal spaces. In some cases, a definite thrill could be felt. Angiography revealed prominence of the pulmonary conus with dilatation of the pulmonary vascular tree.

Eppinger et al. (6) have reported interesting and significant findings in their study of the circulatory dynamics in cases of patent ductus arteriosus. These findings may be summarized as follows: (1) Forty-five to seventy-five per cent of the blood entering the aorta from the left ventricle may pass through the patent ductus into the pulmonary artery. This shunt was unidirectional only, from the aorta to the pulmonary artery. (2) There was a marked increase in the work of the left ventricle. In some cases, it was calculated that the work of the left ventricle was two to three times greater than normal. (3) The arterial blood pressure showed a low diastolic level with a wide pulse pressure as a result of the shunt from the aorta to pulmonary artery. (4) Venous pressure was normal in those cases in which heart failure was not present. (5) Circulation time was somewhat greater than normally found in similar age groups. (6) Blood volume was consistently increased.

**The Operation**

The patient is placed in a supine position with a small sandbag under the left shoulder. The left arm is abducted and extended toward the head in a modified “statue of liberty” position. A transverse incision is made over the left third interspace from the left sternal border to the anterior axillary line. This incision is carried down to and through the pleura; the third, and sometimes the second, costal cartilage is cut. The lung is allowed to collapse and a self-retaining rib retractor is inserted. The mediastinal pleura is incised to expose the pulmonary artery and aortic arch. The ductus and the immediately adjacent recurrent laryngeal nerve are then identified. When the ductus is satisfactorily isolated, it is doubly ligated. The mediastinal pleura is resutured and the chest wall is then closed.

**Anesthetic Management**

Premedicant drugs were used in accord with the principles emphasized by Waters (7).

It was our practice to bring the younger children to the operating room with an intravenous cannula already inserted into a leg or ankle vein; with older children and adults, a large-sized needle was inserted into an arm vein before the operation was begun. These precautions were taken because of the danger of severe hemorrhage from the open ductus and the pulmonary artery. A pint of blood was ready in the operating room for each patient; in addition, supplies of plasma were immediately available on the operating floor. In cases of infected
patent ductus arteriosus, it was wise to have 2 pints of blood available
since the danger of hemorrhage is greater in these cases.

The average patient with no complications suffers but little loss of
blood. Therefore, the intravenous drip was maintained at a slow
rate. I emphasize this minor point because these patients have an
increased blood volume.

In one case avertin-cyclopropane was used, in 19 cases cyclopropane
was the sole agent, and in the remaining 10 cases, cyclopropane-ether
mixtures were used, with cyclopropane as the primary agent. Cyclo-
propane offers the advantages of a rapid induction, and quiet un-
stimulated respirations. Of late, I have been adding small amounts of
ether (15 to 25 cc.) to cyclopropane; this has served to combat the
tendency toward laryngospasm and cardiac arrhythmias with cyclo-
propane. No cases of "cyclopropane shock" were observed. As for the
depth of anesthesia, middle second plane was adequate.

Of the 30 cases, 7 patients were intubated by the oral route. The
reasons for intubation included laryngospasm and the training of anes-
thesiology residents; in one child coexisting bronchiectasis necessitated
intubation. Endotracheal intubation is not imperative; a tight-fitting
mask was completely satisfactory in the majority of cases.

**Anesthetic Problems**

Both the negative and positive aspects of pertinent anesthetic prob-
lems will be considered.

Certain negative features are as follows. In the majority of cases
the lung parenchyma is normal; this is comforting to the anesthetist.
Thus, there is no concern about hemorrhage into the bronchial tree, as
with lung abscess, bronchogenic neoplasms and pulmonary tuberculosis.
Also, there is no fear of flooding the bronchial tree with purulent se-
cretions as in bronchiectasis. In the absence of such hazards, the
burdens of the anesthetist are lightened.

There is no surgical manipulation or traction of pulmonary struc-
tures. As a result, one may have no concern about disturbing cough
reflexes or untoward circulatory and vagal phenomena which may arise
from instrumentation and traction of the pulmonary hilum as in cases
of pneumonectomy and lobectomy.

Another negative aspect which should put the anesthetist at ease
is the fact that there is no manipulation of the heart. The operation
concerns itself only with the patent ductus and its associated great
vessels. The operative procedure *per se* produces no cardiac distur-
bances, as arrhythmias. The arrhythmias observed in the cases at this
hospital were proved to our satisfaction, to be caused by cyclopropane.
It is conceivable that poorly placed packs may exert undue pressure
upon the heart and that an enthusiastic intern may pull too vigorously
upon the retractor and thus produce cardiac arrhythmias. I have not seen these occur.

Under the positive features of the anesthetic problems will be considered the viewpoints of the anesthetist and the surgeons, although these are alike in their fundamentals.

From the anesthetist’s point of view, the primary anesthetic problem is one common to all chest surgery when an open pneumothorax is produced. It is the prevention of “pulmonary decompensation” with excessively active movement of the diaphragm and thoracic cage, shifting of the mediastinum with each phase of respiration, “pendelluf,” hypoxia and hypercapnia. The failure to eliminate pulmonary decompensation would lead to well-known hemodynamic alterations.

The surgeon is less concerned with physiologic problems; his prime request is for a “quiet chest,” an open chest whose movements do not interfere significantly with the surgical procedure. At best, the surgeon works on a “moving target,” an actively pulsating structure. If, to these pulsations, are added a heaving chest wall and significant shifting of the mediastinum, the surgeon’s task is doubly difficult. It must be remembered that the patent ductus arteriosus is a fragile structure, particularly in the infected cases; usually the older the patient, the thinner the wall. It is not uncommon to find the ductus adherent to the pulmonary artery, thus necessitating precise and careful dissection. Thus it is imperative that the chest is quiet to prevent pulmonary decompensation.

In the majority of cases a quiet chest has been attained by the use of irregularly intermittent positive pressure (approximate rate of 8 to 10 per minute) with full insufflation of the lungs about every five or six minutes. Two children showed excessive mediastinal movements which had to be eliminated with “controlled respiration.” The technic of “compensated respiration” (regularly intermittent positive pressure) recently described by Burstein (8) would seem to meet the physiologic demands of the patient when the chest is open more effectively than the technic I have used. As yet my experience with “compensated respiration” is limited.

**Some Clinical Observation during the Operation**

To the anesthetist who has had no experience with surgical procedures on the patent ductus arteriosus, certain questions must inevitably occur.

Does the dissection or ligation of the patent ductus produce any reflex cardiovascular phenomena? I have observed none. It is conceivable that in the course of the dissection, the left vagus nerve may be stimulated with resulting bradycardia or cardiac arrhythmia. I have not observed any evidence of vagal stimulation.

Does the sudden closure of the shunt from the aorta to the pulmonary artery have any untoward effects upon the heart and circulation?
This question was considered by Gross (9) when he suggested that a temporary closure of the ductus for two to three minutes be done with careful observation of the patient's color, blood pressure, pulse and cardiac action. I have seen no deleterious effects; our observations at this hospital all point to a salutary effect of the closure upon the heart and circulation. The cardiac action, tumultuous and exaggerated before the ligation, becomes quieter and smoother, a striking change which should be expected with the decrease in the work of the heart. In some cases, a decrease in pulse rate was observed. In most patients in whom a low diastolic pressure existed with wide pulse pressures, ligation of the ductus was followed promptly by a rise in diastolic pressure and narrowing of the pulse pressure. These changes naturally follow the increase in peripheral resistance produced by closure of the patent ductus.

In the infected case, is there any danger of loosening thrombi and producing embolic phenomena? At no time during the intra-operative and postoperative course of any patient was there reason to suspect that such embolization occurred. Touroff (10) has had 2 cases in which minor pulmonary infarctions occurred during the postoperative period.

Complications

Anesthetic Complications.—Other than cyclopropane arrhythmias and laryngospasm necessitating intubation in 2 cases, there were no anesthetic complications.

Operative Complications.—There was one death on the operating table; this occurred in a 63 year old woman with subacute bacterial endarteritis. This fatality followed severe uncontrollable hemorrhage when a flimsy, sclerotic ductus tore open upon ligation. In 2 cases severe hemorrhagic shock followed the inadvertent tearing of the pulmonary artery in the course of the dissection of the ductus; in both cases hemorrhage was controlled and rapid resuscitation was effected with prompt blood transfusions.

No patient in this series showed paralysis of the left recurrent laryngeal and left phrenic nerves, complications which have been observed (10).

Postoperative Course

There were no postoperative respiratory or circulatory complications in the 20 uninfected cases; these patients had remarkably smooth and uneventful postoperative courses. All of the patients without infection were considered cured except one in whom ligation of a ductus was impossible; this patient was found to have a direct communication from the aortic to the pulmonary artery, without any evidence of a ductus.
Of the 9 patients without infection who survived the operation, 3 were unimproved and eventually died; it can be assumed that an associated endocarditis was present in the cases. Six patients with infection were cured.

SUMMARY

A study is presented of 30 cases of patent ductus arteriosus in which ligation was performed.

The pertinent physical findings and hemodynamic derangements in these patients and a brief description of the operative procedure are reviewed.

The problems of fluid therapy and anesthetic management are discussed.

The average candidate for surgical ligation of the patent ductus arteriosus is a good anesthetic risk and offers few anesthetic problems. The satisfactory physical status of these patients, their normal lung parenchyma, the absence of cardiac and pulmonary manipulations and the freedom from untoward operative respiratory and circulatory reflexes simplify the anesthetic management. The only major anesthetic problem is one common to all open chest surgery, the prevention of pulmonary decompensation.

REFERENCES