ABSTRACT

Congenital cardiac surgery is one of the most challenging and fascinating branches of modern medicine which continues to advance in areas and improving outcomes, post-operative and pre-operative care. Patent Ductus Arteriosus was the first congenital heart lesion to be successfully corrected surgically. The landmark surgery was performed by Dr. Robert E. Gross in 1938 and opened up the possibility of subsequent surgical correction of various other lesions, which were considered to be untreatable previously. The first successful surgical closure of persistent ductus arteriosus (PDA) was preceded by years of work and contributed by various surgeons, physicians, and anatomists, dating all the way back to the 1st century. They are all worthy of recognition and praise. This article covers the important events related to PDA lesions including its first identification, followed by its description in various texts and sources over the course of time, failed attempts at surgical correction, and disputes regarding credits. These contributions to the branch cannot be overstated and serves as an inspiration to cardiac surgeons all over the world and to students, interns, and newly graduated doctors as well, who would one day like to be part of this fascinating branch.

Key words: Cardiac surgery, congenital cardiac surgery, congenital heart disease, history of medicine, patent ductus arteriosus

INTRODUCTION

Modern-day cardiac surgery is the epitome of high technology surgical therapy. It is a fascinating branch of medicine which amazes the minds of the patients, physicians, and cardiac surgeons. Due to an extraordinary amount of laboratory and clinical research along with the enormous resolve and artistry of cardiac surgeons, we have reached this era of excellence in this surgical field. It is essential to acknowledge and get inspiration from old ideas, proposals, failures, and rejections – all of which has contributed to the current state of this branch. Through this article we will look at one of the most historically significant events in the history of congenital cardiac surgery: evolution of patent ductus arteriosus repair.

The persistent arterial duct, also named persistent ductus arteriosus (PDA) or patent ductus arteriosus is a congenital heart abnormality defined as persistent patency of the lumen of the foetal ductus arteriosus in term infants beyond the neonatal period. Persistence implies that the duct is present after the time of its expected closure and therefore is a pathological state.

It was one of the first cardiac lesions to be recognized. The ductus arteriosus may persist in a variety of shapes and sizes. The size and shape of the PDA are important determinants of resistance to blood flow and also have important implications regarding the method of interventional closure.¹

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NORMAL ANATOMICAL CLOSURE

The process of closure of the arterial duct occurs in two steps. Initially, medial smooth muscle contraction produces increased wall thickness and shortening and protrusion of the intimal cushions. This results in functional closure 10–15 hours after birth in full-term infants. The second stage of the closure is due to proliferation of connective tissue in the intima and media. Atrophy of smooth muscle cells ultimately transforms the muscular vessel into a non-contractile ligament represented by a mass of dense elastic and fibrous tissue known as ligamentum arteriosum.[2] The arterial duct is completely closed by 8 weeks of age in 88% of infants with a normal cardiovascular system.[3]

EVOLUTION OF SURGICAL MANAGEMENT

129 AD
Patent ductus arteriosus is known from the ancient times as Galen of Pergamon, a Greek anatomist and physician at 129 AD, who first discovered and described multiple aspects of fetal circulation, including patent ductus arteriosus and foramen ovale, although at the time he did not fully understand the importance of this feature.[4]

1564
The name DUCTUS ARTERIOSUS APERTUS is generally traced to Leonardo Botallo (Leonardus Botallus), the Italian anatomist and surgeon. Botallo claimed, in his brief publication of 1564, “De catarrho commentarius,” that he had discovered a “duct,” but the opening he described connects the right and left atria. He called it the “vena arteriarum nutria.” This opening corresponds to the anatomic feature we now known as the Foramen Ovale. Many years later, Botallo’s work, Opera Omnia (1660) included an illustration of the ductus arteriosus (“canalis à pulmonali arteria tendens in aortam”). This illustration probably gave rise to the assumption made by latter authors that Botallo had discovered this anatomic structure.[5-7]

1898
In 1898, George Alexander Gibson described the classic “machinery murmur” associated with PDA.[8]

1907
The first person to come up with the idea of possibility of surgical closure of the duct was John Cummings Munro, a Professor of Surgery at Tuft’s, Boston, based on studies postmortem. He described and first proposed the idea of ductus ligation in an article read before the Philadelphia Academy of Surgery on May 6, 1907. He never had a case to try the suggested procedure.[9]

1920s and early 1930s
The British surgeon Russell Claude Brock reported that the famous American surgeon Evarts Ambrose Graham (1883–1957) also planned surgical treatment of the open ductus arteriosus in the early 1920s. He told Dr. Brock that, in the early 1920s, he became convinced that it was desirable and feasible to close the persistent ductus arteriosus.

He subsequently met the Professor of pediatrics at St. Louis Children’s Hospital, explained to him his thoughts and plans, and requested if a patient could be sent to him for the procedure. The pediatric professor in response sent along a man aged 53 years, presumably to prevent such an operation in a child, because cardiac surgery in children did not yet exist at that time. Graham commented that this action probably delayed the introduction of this form of treatment by about 15 years.[10]

Another known attempt to perform an operation was done in London by Laurence O’Shaughnessy. The procedure was never implemented because it was a misdiagnosis. In fact, the patient had a pulmonary artery stenosis and patent ductus arteriosus was transformed into the ligament.[11]

1936
Maude Abbott, known for her 1936 Atlas of Congenital Heart Disease, had systematically analyzed the specimens of congenitally malformed hearts held by the McGill Medical Museum in Montreal and showed that endocarditis developed in more than 25% of patients with a ductus arteriosus persistens if they reached puberty.[12]

1937
John William Strieder attempted to close a ductus at Massachusetts Memorial Hospital in Boston, on the advice of the cardiologist Ashton Graybiel, on March 6, 1937. Strieder received referral of a 22-year-old woman with an open ductus and bacterial endocarditis. Due to short length of the duct, the planned procedure was not performed and only partial closure was achieved. There was immediate post-operative improvement of the patient’s condition. The classical murmur of an open duct was no longer audible. The patient however passed away 4 days later. Postmortem findings indicated extensive vegetation.[13]

1938
Dr. Robert E. Gross performed the first successful correction of patent ductus arteriosus on a 7-year-old girl, Lorraine Sweeney on August 26, 1938 at Brigham
and Boston Children’s Hospital. He was the chief resident at the time, with 33 years of age. It is worth noting that Dr. Gross initially failed to secure permission from his superior Dr. William Ladd (known for Ladd’s Procedure, Ladd’s Bands) to perform this procedure. He only was able to go ahead once Dr. Ladd left for vacation, and his deputy gave Dr. Gross the necessary go ahead to perform this procedure. Dr. Gross planned to operate on two patients on the same day in case the first surgery is unsuccessful. Once Dr. Ladd returned, he was not pleased about the whole scenario and is reported to have dismissed Dr. Gross in 1943, but later reinstated him under public pressure.[14,15] After initial success, R. Gross reported his first four cases of successful ductus ligation.[16]

1939

John C. Jones and Lewis T. Bullock, in Los Angeles, tried in vain to obtain the permission of the relatives of patients with a patent ductus for the operation. Only after Bullock was able to report the successful operation carried out by Gross, did he receive parental consent. His first case was that of a 13-year-old boy who underwent the operation on March 28, 1939. By April 10, 1940, this group was able to report ductus ligation in 13 patients.[17]

Several reports and publications claim that the German surgeon Emil Karl Frey (1888–1977) probably closed a ductus before Gross. [18,19] Documentation of this was no longer to be found after the World War II. However, Frey himself wrote in his autobiography “Rückschau und Umschau,” published in 1978, that even though he performed the procedure on a 14-year-old boy in 1939, he waited for more cases before reporting the procedure, as he believed he needed more substantial data. Before he could complete his objective, World War II broke out, which affected his work. As Robert Gross was the first to report about the successful ligation of ductus arteriosus, the credit for the first procedure is often attributed to him.[20]

1939

Oswald Tubbs (also known for Tubbs Dilator), on December 5, 1939 successfully ligated a patient with infected patent ductus at St. Bartholomew’s Hospital in London. The causative organism was found to be Haemophilus influenzae.[21]

1940

On January 27, 1940, Arthur S. W. Touroff ligated an infected ductus at the New York Mount Sinai Hospital. Shortly before, Gross had regarded bacterial endocarditis as a contraindication to the operation because surgical manipulation might mobilize vegetations, leading to embolism and severe bacteremia. Touroff, however, believed that spontaneous pulmonary embolization was already frequent in these patients and that it would not be increased by manipulation. Touroff’s 29-year-old patient, who had endarteritis caused by Streptococcus viridans, was operated on through a left anterior thoracotomy in the third intercostal space.[22]

1941

Dr. Robert E. Gross encountered the first fatal post-operative complication in the form of Duct Transection by the ligature. Two girls, a 15-year-old and a 5-year-old, died postoperatively due to this complication and prompted Dr. Gross to modify the operation and perform surgical transection of the duct and closure of both ends. Dr. Gross transected the ductus for the first time on May 26, 1941. Across the Atlantic, Clarence Crafoord a Swedish surgeon had also transected a ductus and closed both ends in May 1941, most likely before Dr. Gross, and was probably the first case.[23]

1966

Werner Porstmann was the first to close a ductus by catheter technique. The first procedure was performed on a 17-year-old patient in 1966 at the Charité Berlin, in the then German Democratic Republic. Closure was accomplished by implantation of an expandable plug within the arterial duct. Although the required delivery system was much too large to be of practical use in small children, this report pointed to the possibility that repair of congenital heart defects could be accomplished by transcatheter techniques.[24]

1976

Michael A. Heymann and colleagues demonstrated the closure of patent ductus arteriosus in premature infants using non-steriodial anti-inflammatory drugs (NSAIDS). They administered Aspirin and Indomethacin to 18 premature infants and were able to demonstrate positive result in majority of the infants.[25]

1979

Rashkind and colleagues in 1979 reported the first successful catheter closure of a persistent arterial duct in a child weighing only 3.5 kg by deploying a double-disc percutaneous device. In the following decades many advances and refinement were done to the catheter-based closure of the ductus, and it still remains the most commonly used technique except cases of very large ductus arteriosus and very low-birth-weight infants, where open surgical intervention still remains the procedure of choice.[26]

1991

François Laborde in 1991 performed the first video-assisted thoracoscopic (VATS) PDA closure. In Laborde’s series of 332 consecutive pediatric patients,
1992

Cambier and colleagues reported the first case of successful transcatheter PDA coil embolization in 1992. This method was adapted from the technique used in the preceding decade to embolize fistulae, arteriovenous malformations, and other vascular abnormalities. This technique immediately gained wide popularity for its low cost, excellent safety, efficacy and for its adaptability to a wide spectrum of patients ranging from infancy to adulthood.²⁸

Current treatment strategies include pharmacologic closure, percutaneous closure in the catheterization laboratory, video-assisted thoracoscopic (VATS) hemoclipping occlusion and conventional posterolateral thoracotomy with ligation. Percutaneous closure is effective in the treatment of children and adults with PDA. Initial attempt at pharmacologic PDA closure remains the initial therapeutic modality at most centers.

DISCUSSION

Although many surgeons have claimed or presumed to have performed surgical repairs before Dr. Robert E. Gross, absence of specific dates and data regarding such operations lead to an incomplete chronology of events. But it is worth noting that congenital heart disease started to be considered as a treatable condition when, in 1938, Robert Edward Gross first successfully ligated a persistent ductus arteriosus. This event paved the way to modern cardiac surgery.

On an interesting endnote, it is worth mentioning that in 1939 Helen Brooke Taussig visited Gross after his successful ductus operation in Boston. Taussig asked Gross whether he could construct a ductus for her, she disclosed to him that she thought creating a surgical shunt will greatly benefit cyanotic children, but Gross was not interested. Gross seemed to have thought that the construction of such a shunt would lead to pulmonary flooding. After Taussig had returned to Baltimore, she approached Alfred Blalock. Eventually, Taussig convinced Alfred Blalock for her operation, and the Blalock-Taussig shunt was constructed in the first patient with Tetralogy of Fallot on November 29, 1944.²⁹

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Conflicts of interest

There are no conflicts of interest.

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