SURGERY FOR THE PERSISTENT DUCTUS ARTERIOSUS: A REVIEW OF 625 CASES

CHRISTIE TAN TIONG TEE

INTRODUCTION

Surgery for the persistent ductus arteriosus (PDA) is almost 50-years-old. It started with Robert Gross in 1938 who successfully ligated the PDA in a seven-year-old girl.[1] Incomplete obliteration, ligatures cutting through the ductus and recanalisation of the ductus remained troublesome possibilities with this method of dealing with the PDA. Dividing the ductus and suturing each divided end separately would eliminate these possibilities. Gross was quick to recognise this and advocated division in all cases to remove any doubt of incomplete obliteration.[2] Jones supported this concept but also stressed that division and suture of the PDA was not to be taken lightly for the fatal consequence that could arise from inexperience.[3] There were those who continued to have satisfactory results with ligation of the PDA and persisted with this method (Blalock,[4] Clagett, Kirklin, Ellis and Cooley,[5] Panagopoulos, Tatooles, Aberdeen, Waterston and Bonham Carter[6]).

The debate continues between ligation on one hand, and division and suture on the other and it appears currently to favour the latter. This paper reviews our experience with surgery for the PDA over the past five years.

METHOD

A retrospective review of all cases of uncomplicated PDA presented for surgery from April 1982 to February 1987 was carried out. Data was obtained from case records available from the Departments of Cardiology and Cardiothoracic Surgery of the Kuala Lumpur General Hospital in Malaysia.

All cases were first examined and studied by one of five cardiologists who recorded their findings. These were then referred for surgery. All cases were seen by one of the seven surgeons involved in this series including the author, first prior to surgery and again in the immediate postoperative period and in the clinic's follow-up. The cardiologist concerned also reviewed the patients postoperatively and in the clinic.

A total of 645 patients underwent surgery for the PDA from April 1982 to February 1987, 534 (83%) at the Kuala Lumpur General Hospital, and 111 (17%) at the Klang General Hospital. Only 625 (97%) case records were available for review.

RESULTS

Observations

There were 458 (73.3%) females and 167 (26.7%) males, a ratio of 3:1 in our series. Age ranged from four months to 52 years with the largest group being in the one to five years range. Racial distribution showed a predominance of Malays in line with the general population; the geographical distribution may have been influenced by the source of our referrals (Tables I – III).

The commonest presentation was the incidental finding of a continuous murmur in the pulmonary area when the patient was seen by a medical practitioner in 408 cases (65%) (Table IV). Re-

Christie Tan Tiong Tee, MBBS (S'pore), FRCS (Ed)
Department of Cardiothoracic Surgery
General Hospital
50586 Kuala Lumpur, Malaysia

TABLE I
AGE DISTRIBUTION OF PATIENTS

Age (years)	Number	(%)
<1	14	2.2
1–5	271	43.4
6–10	186	29.8
11–20	102	16.3
21–30	39	6.2
>30	13	2.1
Total	625	100

TABLE II
RACIAL DISTRIBUTION OF THE PATIENTS

Race	Number	(%)
Malay	324	51.8
Chinese	165	26.6
Indian	64	10.2
Iban	48	7.7
Kadazan	11	1.8
Dayak	7	1.1
Others	6	1.0
Total	625	100

TABLE III
GEOGRAPHICAL DISTRIBUTION OF THE PATIENTS

States	Number	(%)
Sarawak	122	19.5
Johore	88	14.1
Wilayah Persekutuan	73	11.7
Perak	66	10.6
Penang	54	8.6
Selangor	45	7.2
Sabah	39	6.2
Kedah	30	4.8
Malacca	27	4.3
Kelantan	26	4.2
Negeri Sembilan	25	4.0
Pahang	20	3.2
Perlis	6	1.0
Terengganu	4	0.6
Total	625	100

TABLE IV
MODE OF PRESENTATION

Presentation	Number	(%)
Continuous murmur	408	65.3
Respiratory tract infection	185	29.6
Shortness of breath	28	4.5
Infective endocarditis	2	0.3
Failure to thrive	2	0.3
Total	625	100

current upper respiratory tract infections (URTI) was half as common in 185 cases (30%). Others presented with shortness of breath in 28 cases (4%) and two cases each presented with infective endocarditis and failure to thrive.

Associated cardiac anomalies found in our patients were ventricular septal defects 12 cases, two of whom had concomitant aortic regurgitation; aortic stenosis nine cases; mitral regurgitation nine cases; pulmonary incompetence four cases; aortic and tricuspid regurgitation one each combined lesions of mitral stenosis and aortic stenosis one and aortic regurgitation and stenosis one case. Coarctation of the aorta with PDA was left out of this series.

Other associations such as congenital rubella with cataract and deafness were found in 15 patients. Two sets of siblings and one set of twins were found. Two patients with PDA were unrelated twins and another had a mother with PDA. Other associations were measles and congenital heart block three each; G6PD deficiency, β- thalassaemia, cleft lip and pallate, and left superior vena cavae two each; and bilateral inguinal hernia, hydrocoele, scoliosis, congenital constrictive ankle bands, hydrocephalus, extranumery digit, imperforate anus, Down's syndrome, Klippel-Feil syndrome, torticollis, schizophrenia and Bombay blood group one each.

Preoperatively all our patients had the characteristic continuous murmur over the pulmonary area. They all showed signs of a left to right shunt and a hyperdynamic circulation consistent with a PDA.

Echocardiography showed dilated left cardiac chambers and a dilated pulmonary artery with a hyperdynamic heart in all our cases. Actual visualisation of the ductus on echocardiography was only consistent in our later cases, 95 in all (15%) suggesting a learning curve with this modality. Difficulty in visualising the PDA still remains in our adult patients today because of poor windows.

Cardiac catheterisation was performed in 240 (38.5%) of our cases, the majority of whom were early in our experience to exclude other cardiac anomalies and to assess the severity of pulmonary vascular disease. 97 (40%) of those studied had normal pulmonary artery pressures (less than 40 mm Hg systolic); 47 (20%) had mild pulmonary hypertension (40-60 mm Hg systolic); 41 (17%) had moderate pulmonary hypertension (61-90) mm Hg systolic); 44 (18%) had severe pulmonary hypertension (more than 90 mm Hg systolic) and 11 had no available data. Degree of shunting ranged from 1.2 : 1 to 14.5 : 1.

Operation was carried out via a posterolateral thoracotomy through the left third or fourth intercostal space. Double ligation using ductus silk ties was used and the wound was closed in layers. A chest drain was inserted except in those done extrapleurally. Division and suture were employed in four cases of ducts torn while attempting ligation and in another 12 cases where the PDA was short and unduly wide. Cardiopulmonary bypass and closure of the PDA from the inside of the pulmonary artery was used in three cases because of extreme difficulty at the second operation via the previous thoracotomy site. The ducts ranged from two to 20 mm in diameter (Table V).

TABLE V
SIZE OF DUCTUS

Diameter of ductus (mm)	Number	(%)
<4	20	3.2
$4-8$	477	76.3
$9-15$	113	18.1
>15	15	2.4
Total	625	100

Surgical Results

There were no operative deaths and no deaths during the two to 50 months follow-up. Average post-surgery hospital stay was 8.4 days (4.99 days). Two patients required prolonged hospital stay: one for 89 days because of paresis of both legs from prolonged aortic cross-clamp time to repair a torn duct; the other for 99 days following a complicated repair using cardiopulmonary bypass and requiring prolonged ventilatory support (Table VI).

A residual PDA is first suspected upon hearing the persistence or reappearance of the characteristic continuous murmur. This was found in 29 patients, 12 of whom have been confirmed on repeat cardiac catheter studies to have a residual PDA. Of the 17 remaining, 8 were found from repeat studies not to have a PDA but other cardiac anomalies such as pulmonary incompetence and ventricular septal defects with aortic regurgitation; eight patients are awaiting further study and the murmur in the last patient disappeared after two months.

Short systolic murmurs without a diastolic component were heard in 167 (27%) of our patients. Their significance is questionable as 47 (28%) of these disappeared on subsequent clinic follow-up. We believe most of these are functional and flow-related. Further follow-up is necessary to substantiate this.

TABLE VI
METHOD OF SURGERY

Method of surgery	Initial attempt	(%)	Repeat surgery	(%)
Double ligation	610	97.6	5	55.6
Division and suture	15	2.4	1	11.1
Transpulmonary cardiopulmonary bypass	0	0.0	3	33.3
Total	625	(100.0)	9	(100.0)

Repeat operations were required in nine patients (1.4%). All of them had the characteristic continuous murmur and was confirmed by repeat cardiac catheter study to have a residual duct. Religation was used in five patients, cardiopulmonary bypass and transpulmonary closure in three patients, and division and suture in one. Another three patients are awaiting repeat surgery.

Complications such as hoarseness occurred in 13 patients, all of whom improved on follow-up. Wound breakdown was found in eight patients and chest wall haematoma in five. Collapse of right segments was found in four patients and three patients each had pneumothorax and chest infection. Isolated cases of allergy to plaster, reactive depression, paresis of both legs and prolonged ventilatory support were additional complications.

DISCUSSION

Large-scale surgery for the PDA in the Government medical services started in Malaysia in 1982 when the Department of Cardiothoracic Surgery was established at the Kuala Lumpur General Hospital. In March 1986, the department ventured to Klang General Hospital to reduce the waiting list for surgery for the PDA. The number in our series measures well with others collected over a longer period: Gross and Longino -- 412 patients over 12 years 1938-1950;[7] Jones – 889 patients over 25 years 1939-1964;[3] Panagopoulos *et. al.* – 936 patients over 23 years 1946-1969;[6] Greenlane Hospital Auckland – 246 patients over 18 years 1966-1984;[8] University of Alabama Hospital – 261 patients over 17 years 1967– 1984.[8]

Our patients showed a preponderance of females in the ratio of 3:1, more than that shown by the series of Jones and Panagopoulos *et. al.* Most of our patients (75%) were operated on before the age of ten years; 271 cases (43%) were operated between the ages of one to five years. Gross and Longino also had most (60%) of their cases operated before the age of ten years, but the majority of them were between the ages of five to ten years. They suggested that the best chances for smooth and relatively easy surgical procedures were generally provided between the ages of six to 12 years. Surgery for the PDA has come a long way and we are tending to operate on patients earlier. Today, surgery for the PDA in the preterm infant is a reality.[9]

Gross and Longino suggested that in 95% of cases simple examination with stress upon an intelligent auscultation can lead to a rapid and accurate recognition of a PDA in 1951. Our experience shows this to be true today. The majority (65%) of our patients presented with the characteristic continuous murmur over the pulmonary area, picked up by conscientious medical practitioners seeing the patient for an unrelated cause. Visualisation of the PDA by noninvasive echocardiography to confirm its presence has recently become more consistent, except in adults. Cardiac catheterisation has helped us exclude other cardiac anomalies where doubts exist and also allowed us to identify those with elevated pulmonary artery pressure.

Our practice of predominently ligating the PDA (97% of cases) is no longer practised by most groups who prefer division and suture. Gross and Longino had only 43 (10%) of 412 cases ligated, Jones 61 (7%) of 889 cases and University of Alabama Hospital 41 (16%) of 261 cases. The only large series where ligation was predominently used was that of Panagopoulos *et. al.*, (99%) cases. Their series however contained many infants and toddlers. Barratt-Boyes from Greenlane Hospital and Kirklin from University of Alabama Hospital[8] now recommend ligation only in the neonates and infants. Closure of the PDA under cardiopulmonary bypass was first described by Goncalves-Estella *et. al.*[10] This has been recommended for older patients in the fifth and sixth decades where the aortic end of the ductus is calcified and the ductus is short.[8] We used this technique in three cases because repeat surgery via the previous thoracotomy approach was extremely difficult and hazardous. O'Donovan and Beck also found this technique simple and safe in repeat surgery for the PDA.[11] The University of Alabama Hospital performed two cases of transpulmonary closure of the PDA on cardiopulmonary bypass.

Postoperative persistence or reappearance of the continuous murmur over the pulmonary area suggests a residual ductus Our incidence of residual ducts at 12 cases (1.9%) was ten times less than that of Jones with 12 cases in 61 ligated (20%) but four times more than that of Panagopoulos *et. al.* (0.4%).

Gross and Longino found that in 90% of their cases all murmurs disappeared following division of the ductus. In their remaining patients a systolic murmur persisted, 28 of whom were found to have residual cardiac defects and another 28 with no suggestion of cardiac anomaly whatsoever. The systolic murmur heard in the latter group were believed to be functional. Our experience with persisting systolic murmurs showed that a good proportion of them disappeared with time and required no more than close follow-up.

Early and late mortality in our series was nil. Our patients were uncomplicated cases of PDA with no major congenital anomalies and with few patients below the age of one year. Our good results exemplify the importance of supervision and close cooperation among the staff concerned. Gross and Longino also had no mortality attributed to surgery even when division and suture was used in 90% of cases. Their eight deaths were due to poor propane anaesthesia, infection and a hypoplastic aorta. Jones had six deaths (0.9%) in 642 cases of uncomplicated PDA over the age of one year. Reoperation for those ligated initially was hazardous, mortality 3.1% while division and suture for uncomplicated PDA had a mortality of 0.2% in his series. Panagopoulos *et. al.* had five deaths (0.6%) in 739 patients with no other major congenital anomaly, cardiac or otherwise. Kirklin at the University of Alabama had no hospital deaths in 261 cases.

Our surgical complications of hoarseness, wound breakdown, atelectasis and other minor complications have been well documented by Jones and Panagopoulos *et. al.* All these complications resolved with time and there were no residual impairment.

CONCLUSION

We have been a little late embarking on surgery for the PDA four-and-a-half decades after its infancy. In this short and recent experience, we have been able to offer surgery to 625 patients with uncomplicated PDA in Malaysia.

Our patients' characteristics matched those of other series suggesting a female preponderance and a predominently young population presenting for surgery, first picked up by the finding of the characteristic continuous murmur. Echocardiography is beginning to play a bigger role in diagnostic confirmation.

Our results suggest that with our experience surgery can be carried out safely and effectively using the ligation method. We had no operative, early and late mortality although our follow-up is still early. We have a 1.9% incidence of residual ductus to date.

Our five years' experience has been considerable providing an opportunity for safe and effective obliteration of the uncomplicated PDA in our general population. We have yet to embark on surgery for the preterm infant with a PDA.

ACKNOWLEDGEMENT

The author wishes to thank Tan Sri Datuk Dr Abdul Khalid bin Sahan, the Director-General of Health Malaysia, for permission to publish this paper. The author is also grateful for the help and encouragement given by the Director, General Hospital Kuala Lumpur, and the heads of the Departments of Cardiothoracic Surgery, Cardiology and Cardiac Anaesthesia, General Hospital, Kuala Lumpur.

REFERENCES

1 Gross RE, Hubbard JP. Surgical ligation of a patent ductus arteriosus. Report of first successful case. *J Am Med Assoc* 1939; 112 : 729.

2 Gross RE. Complete surgical division of the patent ductus arteriosus. *Surg Gynae Obstet* 1944; 78:36-43.

[3] Jones JC. Twenty-five years' experience with the surgery of patent ductus arteriosus. *J Thorac Cardiovasc Surg* 1965; 50: 149–165.

[4] Blalock A. Operative closure of the patent ductus arteriosus. *Surg Gynae Obstet* 1946; 82: 113–115.

[5] Clagett OT, Kirklin JW, Ellis FH, Cooley JC. Surgical treatment of the patent ductus arteriosus. *Surg Clinics of N Amer* 1955; 35 : 965.

[6] Panagopoulos PH, Tatooles CJ, Aberdeen E, Waterston DJ, Bonham Carter RE. Patent ductus arteriosus in infants and children: A review of 936 operations. *Thorax* 1971; 26 : 137–144.

[7] Gross RE, Longino LA. The patent ductus arteriosus – observations from 412 surgically treated cases. *Circulation* 1951; 3 : 125-137.

[8] Kirklin JW, Barratt-Boyes B. Patent Ductus Arteriosus. In: *Cardiac surgery – morphology, diagnostic, criteria, natural history, techniques, results and indications.* John Wiley and Sons 1986 : 679–697.

[9] Ho LY. The management of symptomatic patent ductus arteriosus in premature infants. *J Spore Paed Soc* 1986; 28 : 153–162.

[10] Goncalves-Estella A, Perez-Villoria J, Gonzalez-Reoyo F, Gimenz-Mendez JP, Castro-Cels and Castro-Llorens M. Closure of a complicated ductus arteriosus through the transpulmonary route using hypothermia. *J Thorac Cardiovasc Surg* 1975; 69 : 698–702.

[11] O'Donovan TG, Beck W. Closure of the complicated patent ductus arteriosus. *Ann Thorac Surg* 1978; 25 : 463–465.