Original Research

Closure of a Large Patent *Ductus Arteriosus* in Children and Adults with Pulmonary Hypertension

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Introduction: Surgical closure of a patent *ductus arteriosus* (PDA) in cases with pulmonary hypertension, a short and wide PDA, and/or calcification of the wall of the vessel can be a hazardous procedure. The use of extracorporeal circulation provides the necessary safety for effective closure.

Methods: Four patients (one male), aged 7, 22, 54 and 60 years old, underwent PDA closure. All had pulmonary hypertension (pulmonary artery pressure, PAP 55-85 mmHg, PAP-to-systemic pressure ratio 0.6-0.8) and a wide, short PDA (diameter 9-12 mm) with a calcified wall in 2 cases. The surgical technique involved transpulmonary PDA closure with a synthetic patch under extracorporeal circulation and mild hypothermia (n=2); or double ligation and purse-string suture of the PDA with extracorporeal circulation and normothermia on a beating heart (n=1), or with heart-lung machine on standby (n=1).

Results: Mortality was nil. The postoperative course was mild in all cases. Follow up 3 to 8 years post surgery showed effective PDA closure, PAP within normal (n=3) or at upper normal limits (n=1), and no other sequelae.

Conclusion: The use of extracorporeal circulation allows safe and uncomplicated surgical closure of a PDA in "difficult" cases.

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A patent *ductus arteriosus* (PDA) is usually closed during childhood, by either surgery or therapeutic catheterisation. Sometimes, however, the condition is not diagnosed until adulthood or even later. Surgical closure in asymptomatic patients during childhood in practice involves no greater risk than that of general anaesthesia, while providing a complete cure.[1] If the PDA is of small length and wide diameter, with a wall that is calcified or inflamed and thus friable (as occurs in adults), or if the patient has pulmonary hypertension, then the dissection, closure and division of the PDA by the usual method of ligation via a left thoracotomy may be extremely hazardous.[1-4] The use of extracorporeal circulation (ECC) for cardiopulmonary bypass facilitates the closure of the PDA in such cases. We present our limited experience from the surgical closure of a PDA in 4 patients, with the assistance of ECC.

Methods

From 1995 to June 2001, 4 patients with a PDA underwent surgery at the Onassis Cardiac Surgery Centre (Table 1, patients 1-3) and the "Aghia Sophia" Children's Hospital (patient 4). The patients' demographic data and preoperative characteristics are given in Table 1. All patients underwent cardiac catheterisation and were found to have reversible pulmonary hypertension on a hyperoxia test (delivery of 100% oxygen with measurement of pulmonary pressures before and after). In patient 4 an attempt

Table 1. Patients' preoperative and postoperative data.

No.	Sex	Age (years)	PAP before (mmHg)	Pp/Ps	PDA diameter (mm)	Qp/Qs	NYHA class before	Follow up (years)	PAP after (mmHg)	NYHA class after
1	♀	22	70	0.6	9	2.1	II	8	30	I
2	♀	54	75	0.7	10	1.8	II-III	7	35	I
3	♀	60	85	0.8	12	1.5	III	5	40	II
4	♂	7	55	0.7	10	2.8	III	3	30	I

NYHA – New York Heart Association; PAP – pulmonary artery systolic pressure; PDA – patent ductus arteriosus; Pp/Ps – pulmonary-to-systemic pressure ratio; Qp/Qs – pulmonary-to-systemic flow ratio.

was made to close the PDA during catheterisation, using Amplatzer Duct Occluder No14/12 and Amplatzer Septal Occluder No11 devices, but the large width of the PDA prevented success.

Surgical technique

Access was via a median sternotomy in all cases (Table 2).

Patient 1

The sternotomy, because of the patient's significant scoliokyphosis, was of necessity angled towards the left. The PDA was closed with free ligation and purse-string sutures (with 2 Teflon pledgets) at the aortic end of the PDA ("sandwich"). ECC was on standby but was not used.

Patients 2 and 3

The ascending aorta and *venae cavae* were cannulated and ECC was instituted with systemic hypothermia at 25°C. The large vessels were then prepared: aorta, main pulmonary artery and its branches, PDA. Then, with reduced flow in the ECC circuit and pressure applied with the finger to the main pulmonary artery from outside in order to reduce flow, arteriotomy of the pulmonary artery bifurcation was performed, followed by closure of the pulmonary end of the PDA with a Dacron patch (Figure 1).

Table 2. Intraoperative parameters.

No.	ECC time (min)	Cross-clamp time (min)	Oesophageal temperature (°C)	Surgical technique
1	0	0	Normothermia	Ligation
2	46	29	25	Patch
3	55	32	25	Patch
4	24	0 (beating heart)	33	Ligation

ECC – extracorporeal circulation.

Patient 4

As above, institution of ECC, cooling to 25°C and, with reduced flow in the ECC circuit, closure of the PDA by triple ligation.

Results

The postoperative course of all the patients was excellent. Follow up with echocardiography and colour Doppler showed effective closure of the PDA in all cases, restoration of pulmonary pressures to normal (or upper normal) levels, while the patients' clinical condition also improved (Table 1).

Discussion

From the classic study by Campbell, in 1968, of the natural history of PDA we know that after the age of 2 years the annual mortality among patients with PDA is around 0.5% up to the age of 20 years, 1-1.5% during the third decade of life, 2-2.5% in the fourth decade and about 4% above the age of 40.[5] One in 3 patients with PDA (34%) will have died before the age of 40 years, with a mortality in the general population of 4% in the era of Campbell's study. In light of these data, and because of the risk of developing pulmonary hypertension, acute heart failure, and endocarditis, the existence of PDA is sufficient indication for closure, surgical or invasive.[4,6] Of course, in the case of non-reversible pulmonary hypertension and reverse flow via the PDA (right-to-left), its closure is accompanied by high mortality (23% for pulmonary pressure >70 mmHg[7]). Even in patients who survive, the treatment may not help them improve and may not prevent the creation of *cor pulmonale*.[6-8]

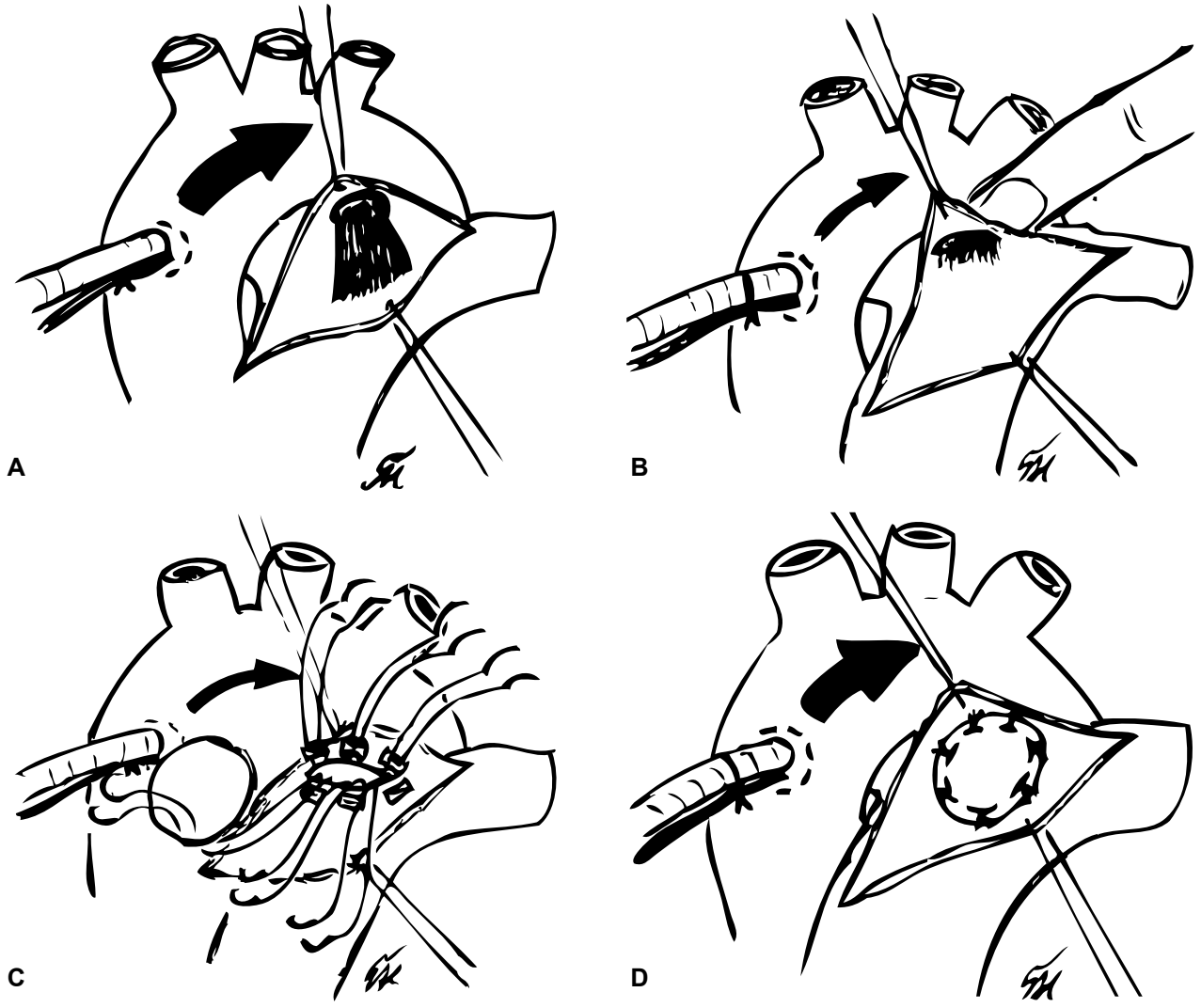

Figure 1. Closure of a patent ductus arteriosus (PDA) using extracorporeal circulation (ECC). A. Under ECC with reduced flow, arteriotomy is performed at the pulmonary bifurcation. B. The PDA is pressed with a finger from outside, reducing flow. C. Single sutures, reinforced with pledgets, are placed at the pulmonary end of the PDA. D. Closure of the PDA is completed with a Dacron patch.

Closure of a PDA in adults or older children is often a surgical challenge. Its fragile wall, as the result of calcification and atherosclerotic lesions, together with the frequent coexistence of pulmonary hypertension, make conventional ligation and division of the PDA an extremely hazardous procedure, sometimes impossible.[6,9] In these cases, the use of cardiopulmonary bypass and ECC (or a bypass shunt) is essential. Of course, apart from the known consequences of such support (systemic inflammatory reaction, etc.) and its financial cost, it entails the full heparinisation of the patient with an unstable surgical field (PDA wall). We consider, however, that its use in specific cases of PDA is essential in order to provide the patient with the greatest possible degree of safety.

Various techniques have been invented for closing the "difficult" PDA: approach via pulmonary arteriotomy or aortotomy, followed by closure of the pulmonary or aortic end of the ductus, respectively. Closure may be achieved simply, with sutures reinforced by Teflon felts.[10] However, closure with a synthetic patch is safer to prevent a possible recanalisation of a closed PDA.[7] Bhati et al were the first to use a balloon catheter (Fogarty), to seal the PDA from inside during suturing of the patch around the PDA ostium,[11] a technique that has been adopted by others, albeit with modifications.[1-3] Toda et al inserted the Fogarty catheter through the centre of the patch into the PDA lumen.[3] In our patients, the surgical field was satisfactorily controlled by low flow

in the ECC circuit and pressure from outside with the surgeon's finger.

There is concern as to whether it is preferable for the PDA to be closed at its aortic or its pulmonary end. Supporters of the former consider that closure of the pulmonary end can pose technical problems, because the pulmonary arterial wall is thin and tears easily. In addition, the *ductus* is left exposed to systemic pressure, with risk of thrombosis, inflammation, or creation of an aneurysm.[9,12] However, there are no reports in the international literature concerning the chances of this iatrogenic *"ductus infundibulum"*, suggesting that the above fears mainly be only theoretical. Furthermore, aortotomy of an aortic wall with severe atherosclerosis is prohibitively difficult.

We conclude that, in patients with a wide and/or calcified PDA, with concomitant pulmonary hypertension, the use of ECC provides safety for an effective and uncomplicated closure of this defect.

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