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# Surgical management of patent ductus arteriosus in newborn infants of low birthweights

A review of 33 cases

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**SUMMARY** Thirty-three infants with low birthweights (<2500 g) and respiratory distress had ligation of a patent ductus arteriosus. During a 30-month period there were no deaths resulting from the operation, but 11 (33%) eventually died from complications of immaturity.

The increased survival of small neonates with hyaline membrane disease has led to an increase in patent ductus arteriosus in such neonates. During the period of this study patent ductus arteriosus occurred in 21% of all newborn infants who weighed <2500 g, and were seen at this hospital; the proportion increased with decreasing birthweight and gestational age.<sup>1</sup> Patent ductus arteriosus often coexists with hyaline membrane disease.<sup>2</sup>

Congestive heart failure may result from a large left-to-right shunt through the ductus arteriosus. Ventilatory support is prolonged and spontaneous closure delayed. Although congestive heart failure may be controlled by ventilatory and medical measures, many of the neonates remain ventilator-dependent and require further intervention by pharmacological or surgical means. A lack of clear evidence incriminating the ductus arteriosus as the cause of the complications associated with hyaline membrane disease (such as bronchopulmonary dysplasia or necrotising enterocolitis), results in uncertainty about the preferred method and timing of ductal closure. We report our surgical experience with patent ductus arteriosus.

## Material and methods

As our institution is a tertiary referral centre, all the newborn infants in our neonatal intensive care unit are referred from other units. Of 239 neonates with patent ductus arteriosus, weighing <2500 g at birth, 33 eventually required surgical ligation of the ductus arteriosus during the period of the study (1 January 1976 to 30 June 1978).

Diagnosis of patent ductus arteriosus was made by palpation of the peripheral pulses and the precordium, and by auscultation.<sup>3</sup> This was supplemented by radiological<sup>4</sup> and echocardiographic evidence of a left-to-right shunt.<sup>5-7</sup> The diagnosis of respiratory distress due to hyaline membrane disease was made in the first 6 hours of life by the usual criteria.<sup>8,9</sup>

Echocardiography was performed in all cases. The mean left atrial (LA) dimension was measured at end-systole from the anterior edge of the posterior left atrial wall to the anterior edge of the posterior wall of the aortic root. The aortic (AO) root was measured at end-diastole from the anterior edge of the anterior aortic wall to the anterior edge of the posterior aortic wall.<sup>10</sup> The left atrial dimension was expressed as a multiple of the aortic root dimension (LA/AO).<sup>6,7</sup>

Thirty of the 33 newborn infants developed signs of congestive heart failure. They were treated initially with digoxin and diuretics, but none responded. If no contraindication to its use existed,<sup>11</sup> indomethacin was given by nasogastric tube in a dosage of 0.1 mg/kg per dose every 8 hours for three doses. The drug was administered to 24 (73%) of the 33 infants under a strict protocol in which renal, haematological, and hepatic functions were monitored from 24 hours before the study until 48 hours after administration.

If treatment with digoxin, diuretics, and indomethacin failed to control congestive cardiac failure and if there was still deterioration of pulmonary function (increasing CO<sub>2</sub> retention, hypoxaemia, and increasing ventilatory pressure), surgery

was used. Poor ventilatory function was often manifested clinically by frequent and severe apnoeic attacks, requiring continued and prolonged ventilatory support with increasing pressures. In this retrospective study, a median period of 8 days elapsed from the time of institution of indomethacin treatment to surgery.

The infant was taken to the operating room where surgery was performed. The patent ductus arteriosus was exposed through a posterolateral incision by either transpleural or extrapleural approach. In each case, the ductus arteriosus was dissected and ligated with one or two heavy ligatures. The external diameter of the ductus arteriosus or the descending aorta, or both, was measured in 27 infants. After surgery, the infant went back to the neonatal unit for care.

## Results

Thirty-three babies underwent surgical ligation of the ductus arteriosus. Their birthweights ranged from 600 to 2400 g (median 1090), with 29 infants weighing <1500 g. The median gestational age<sup>12</sup> was 28 weeks (range 25 to 41); the birthweights of 22 babies were appropriate for gestational age. The median onset of heart murmur was 6 days and of congestive heart failure 11 days (range 4–54). Echocardiography was performed in all cases, and in the 30 infants who developed cardiac failure the mean LA/AO ratio was 1.6 (normal 0.8–1.2), indicating a haemodynamically significant left-to-right shunt, in the presence of normal ventricular compliance.<sup>7</sup> These findings were interpreted in association with clinical signs.

Eight of the 24 infants who had been given indomethacin had softening of their murmurs (in one infant, the murmur disappeared completely only to reappear 24 hours later). This temporary response was supported by a reduction in the LA/AO ratio, but they remained in cardiac failure, or had continuing ventilator dependence, or both, and were therefore submitted to surgical ligation.

In 31 babies, surgical ligation was performed for ventilator dependence because of hyaline membrane disease or recurrent apnoeic episodes, or both.

Measurements of the external diameter of the patent ductus arteriosus were made in all cases. The mean external diameter was  $3.9 \pm 1.0$  (n = 33) and the range between 2 and 6 mm. A comparison of the external diameter of the patent ductus arteriosus and the external diameter of the descending aorta in the 17 infants in whom both were noted showed 6 patients with ductus diameter equal to, or greater than, the descending aortic diameter, 6 with ratio from 60 to 100%, and 5 with a ratio of 50%. The

ducts were large in proportion to the size of the patient.

The median age at surgery was 30 days. This late age at operation was partly a reflection of a conservative approach to surgery adopted in Toronto during the period of the study and was partly due to the earlier use of indomethacin in 24 infants. The median time to extubation was 4.4 days (range 1 to 16). There were no deaths during the surgical procedure, the earliest death occurring 4 days after surgery. Apart from occasional episodes of atelectasis and transient pneumothoraces, there were no longstanding complications directly attributable to surgery.

Four babies of the 33 had late operations. Their birthweights were 820, 870, 1200, and 2300 g. The first 3 of these infants had recovered from their respiratory distress, were extubated, and had their cardiac failure controlled. They were discharged home and were readmitted at 9, 14, and 12 months respectively, for cardiac catheterisation, because of persistent evidence of a left-to-right shunt. At catheterisation, the pulmonary to systemic flow ratios were 3.4, 3.1, and 2.5. Each was extubated on the second postoperative day. They had no radiological evidence of bronchopulmonary dysplasia and all are alive. The remaining infant had Down's syndrome and was found to have a pulmonary to systemic flow ratio of 2.1 at cardiac catheterisation; ligation was performed at 9 months of age.

Eleven babies eventually died, giving a mortality of 33% compared with a total mortality for the whole non-surgical group, during the same time, of 14.7%. This increase reflects the severity of the cardiorespiratory problems in the surgical group.

Ten of these babies required ventilation for severe hyaline membrane disease until the time of surgery and 6 of them developed bronchopulmonary dysplasia from which 5 died. The earliest death from dysplasia was 2 months after surgery. Of the other deaths, 3 babies died of septicaemia, 2 of the late effects of intraventricular haemorrhages, and 1 of a pneumothorax (Tables 1 and 2).

Table 1 *Early deaths*

Birthweight (g)	Gestation (weeks)	Age (days)		Cause of death
		At surgery	At death	
600	25	38	44	Septicaemia
750	28	16	26	Late effects of intraventricular haemorrhage
1070	32	15	20	Pneumothorax
1500	28	16	20	Late effects of intraventricular haemorrhage

Table 2 *Late deaths*

Birthweight (g)	Gestation (weeks)	Age		Cause of death
		At surgery (days)	At death (months)	
709	28	23	2.5	Cerebral atrophy, bronchopulmonary dysplasia
715	33	32	2.5	Acute renal failure, <i>Candida sepsis</i> , necrotising enterocolitis
980	28	20	6	Bronchopulmonary dysplasia
1000	28	14	2.5	Bronchopulmonary dysplasia
1400	32	23	7.5	Bronchopulmonary dysplasia
1670	30	34	4.5	Septicaemia, necrotising enterocolitis
2370	34	14	2.5	Bronchopulmonary dysplasia

## Discussion

The first report of successful ligation of a patent ductus arteriosus was by Gross and Hubbard in 1939.<sup>13</sup> In 1963, DeCanq<sup>14</sup> reported the successful ligation of a patent ductus arteriosus in a 1400-g infant, and Powell<sup>15</sup> ligation in the presence of hyaline membrane disease. Since then, several reports have supported operative intervention for relieving respiratory distress and terminating cardiac failure resistant to medical management. In 21 reports there have been only 6 operative deaths in 366 operations.<sup>16</sup> Overall, only 66% of these infants have survived. Mortality was related to hyaline membrane disease.

Our series corresponds closely to these reported cases in that the majority of infants weighed less than 1500 g and were of less than 30 weeks' gestation. The survival rate of 66% in our series is similar to others. The onset of a cardiac murmur by the end of the first week was taken as the onset of haemodynamic shunting, but there is evidence that left-to-right shunt may start at 2 to 3 days of age in the absence of cardiac murmurs.<sup>17, 18</sup> The explanation given is that the ductus is large and that no turbulence is set up to produce a murmur.

Surgical ligation was performed later in our series than in others.<sup>19, 20</sup> Early ligation may subject more infants to surgery because spontaneous closure might occur in some, even after a bout of heart failure (beyond 30 days). However, continuing ventilation beyond the second week of life appreciably increases the risk of bronchopulmonary dysplasia and the risk of late death from the effects of bronchopulmonary dysplasia. Thus, with the low immediate risk of surgery, the optimal timing of surgery may be within the second week of life.

Prospective studies are needed to compare the merits of treatment with indomethacin and surgical ligation. The controversy over the timing of treatment, whether medical or surgical, requires resolution.

These results show that surgical ligation of the patent ductus arteriosus in babies of low birthweights is a safe procedure, and must continue to play an important role in the care of any infant whose cardiac failure remains resistant to conventional treatment and in whom indomethacin has failed or is contraindicated.

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