Cardiology in the Young

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Ligation of patent ductus arteriosus through left anterior mini-thoracotomy in preterm infants

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Original Article

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Abstract

Objective: Patent ductus arteriosus is an important cause of morbidity and mortality, especially in very low birth weight infants. The aim of the study is to report our single-centre short-term results of preterm patients who underwent ligation through left anterior mini-thoracotomy . *Methods:* Data of 27 preterm infants operated by the same surgeon who underwent Patent ductus arteriosus (PDA) closure with left anterior mini-thoracotomy technique between November 2020 and January 2022 at a single institution were reviewed. The patients were divided into two groups according to their weight at the time of surgery. Data on early postoperative outcomes and survival rates after discharge were collected. *Results:* Twenty-seven patients with a mean (±SD) gestational age of 25.8 (±2.0) weeks and a mean birth weight of 1027 (±423) g were operated using left anterior mini-thoracotomy technique. The lowest body weight was 480 g. Complications such as bleeding, abnormal healing of incision, or pneumothorax were not seen. There were 8 mortalities after the operation (29,6 %). The causes of the deaths were sepsis, necrotising enterocolitis, hydrops fetalis, hepatoblastoma, and intracranial bleeding. There was no statistically significant difference in the rates of complication between the groups. *Conclusions:* Left anterior mini-thoracotomy technique can be performed as the first choice when transcatheter intervention cannot be applied in preterm infants. It provides easy access to the PDA, a good exposure, minimal contact with the lungs, good cosmetic results in early and mid-term and shortens the operation time, especially in very low birth weight preterm babies. However, early ligation may be helpful to minimise the complications related to PDA.

Patent ductus arteriosus (PDA) is one of the most common congenital anomalies of the neonates.[1–3] Persistence of this fetal connection leads to left ventricular volume overload, pulmonary hypertension, increased mechanical ventilatory support, hypotension requiring inotropic support, oliguria/renal failure, or feeding intolerance/failure to gain weight. Surgical closure is considered when medical therapy fails. In preterm infants, surgical closure technique is especially important as you deal with congested lungs. Minimally invasive techniques are more and more used in this manner.[4,5] Among different minimally invasive strategies that have emerged in the last decades, left anterior mini-thoracotomy has been recognised as a safe, efficient, and less expensive technique.[6–9] In this study, we tried to evaluate the effects of the less invasive left anterior mini-thoracotomy technique and share our results.

Materials and methods

This study involved a retrospective review of the clinical and operative records of 27 preterm infants (gestational age < 37 weeks) who had surgical closure of PDA with left anterior mini-thoracotomy technique between November 2020 and January 2022 at a single institution. 27 patients underwent PDA closure with this technique (9 male, 18 female). Same paediatric surgeon operated all the patients. PDA was closed in premature infants who had congestive heart failure despite medical treatment or showed a large left to right shunt on echocardiogram causing increased mechanical ventilatory support, hypotension requiring inotropic support, oliguria/renal failure, or feeding intolerance/failure to gain weight The range of the weight at operation was 480–2700 g. Preoperatively, 26 infants were ventilator-dependent.

Data on early postoperative outcomes and survival rates after discharge were collected. Baseline information of patients is shown in Table 1. The data collected include medical treatment time, preoperative mechanical ventilation support(days), PDA closure with clip or ligation, operation time, intraoperative blood loss, conversion to sternotomy or thoracotomy, use of inotropic agents, surgery-related complications, postoperative length of stay(days),

Table 1. Patient characteristics in all cases

	All cases (n = 27)	
	Mean ± SD (minimum–maximum)	Median [interquartile range]
Gestational age (week)	25.8 ± 2.0	26 (22-31)
Mean birth weight (gr)	1027 ± 423	920 (550-2500)
Mean weight at surgery (g)	1188 ± 553	1020 (480-2700)
Medical treatment time	2.0 ± 1.1	2 (0-4)
Preoperative MV support	24.2 ± 16.2	25 (0-77)
Operation time	18.7 ± 5.5	20 (10-40)
Mean postop LOS	25.2 ± 39.0	6 (0-165)
Mean hospital stay	38.5 ± 52.7	7 (0-193)
Mean PDA size	2.85 ± 0.72	3 (1.7-4.5)
Mean postoperative MV time	16.0 ± 33.3	3 (0-165)

MV: Mechanical ventilation, LOS: Length of stay.

hospital length of stay(days), transfer to another hospital, postoperative mechanical ventilation time(days), complications in the ICU, hospital mortality, and number of patients still alive. All operations were performed in the operating room of our hospital.

Surgical technique

In the operating room, three-lead electrocardiography and pulse oximetry were used for routine monitoring. The patient was under a heater until the operation started. Central venous catheter or invasive arterial monitoring were not used routinely. Adrenalin infusion was started routinely. In left anterior mini-thoracotomy technique, approximately 2–3 cm incision was made through the second intercostal space. The incision was limited to left internal mammarian artery. The lung was retracted with a small rolled gauze gently. A longitudinal incision 1 cm above the phrenic nerve was made. Then, a stay suture was placed at pericardium to visualise the ductus and the pulmonary arteries. After the dissection of the lateral surfaces of the ductus was completed, a clip was placed on the PDA or the PDA was ligated with a 2-0 silk suture. Especially in the case of fragile and thin-walled PDAs, single clip was preferred. The surgical incision was closed with interrupted 4/0 prolene sutures without a chest tube (Fig 1). The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the ethics committee. Permission for this study was granted by the Dr Gazi Yasargil Training and Research Hospital Ethical Committee of Clinical Researches with the decision number 26 and date 11.02.2022.

Routine postoperative care

We transferred all the preterms back to the neonatal ICU. Fentanyl infusion was commenced. Epinephrine infusion was gradually decreased and stopped according to the mean arterial pressure. Mean arterial pressure of less than that for corrected gestational age was defined as hypotension. One hour after the procedure, all preterms had a chest X-ray to exclude possible haemothorax or pneumothorax.

Statistical analysis

Patient cohort was divided into two groups according to their weight at the time of surgery: Group 1 < 1000 g and Group 2 ≥ 1000 g. The SPSS statistical programme for Windows, version 22 (SPSS, Inc., Chicago, IL, United States of America) was used for data analysis. The Shapiro–Wilk test was used for the analysis of compliance with normal distribution. Normally distributed continuous data are presented as a mean ± standard deviation together with its ranges in brackets, and nominal variables are presented as counts and/or percentages. Non-normally distributed continuous data are presented as a mean ± standard deviation and the median parameters with their interquartile ranges in brackets. For statistical comparison of group data, Student's t-test was used for normally distributed continuous variables and Mann–Whitney U-test for non-normally distributed continuous variables. Complication and death incidences for both groups were tested for significance using the Ki-Kare ve Fisher's exact test. All statistical tests were two-sided. A p value of < 0.05 was considered statistically significant

Results

Twenty-seven patients with a mean (±SD) gestational age of 25.8 (±2.0) weeks and a mean birth weight of 1027 (±423) g were operated using left anterior mini-thoracotomy technique. Eighteen were females (66 %), 9 were males (33 %). 17 (62 %) were born at ≤ 26 weeks, and 17 were ≤ 1000 g. According to their weight at the time of operation, the patients were separated into two groups: Group 1 ≤ 1000 g (n: 13) and Group 2 > 1000 g (n: 14). Mean weight of all the patients on operation day was 1188 (±553) (480-2700 g). In Group 1, it was 822 (±169) g, and in Group 2, it was 1528 (±573) g. Statistical difference was significant between Group 1 and 2 : 822 (±169) g, 1528 (±573) g, respectively(p: 0.000). Mean age of all the patients on operation day was 29,7 ± 16,1 days. In Group 1, it was 23 (±12), and in Group 2, it was 36 (±20) days, respectively (p: 0.079). Statistical difference was not significant between Group 1 and 2. Each group had some limitations as all the patients in group 1 were very low birth weight, 7 patients in group 2 were very low birth weight. All of the cases were completed without cardiopulmonary bypass. There was no blood loss during the cases, no surgery-related mortality or no significant difference in operation time between the cases. As the patients had no drainage tube, they had no drainage after the operation. Complications such as bleeding, abnormal healing of incision, or pneumothorax were not seen. Patients' preoperative conditions were analysed in Table 2. Additional comorbidities of the patients before the surgery were 8 bacterial sepsis (29,6 %), 3 necrotising enterocolitis(11 %),1 hydrocephalus (0,3 %), 4 intracranial haemorrhage (14,8%). All of the patients had congestive heart failure and five had a pulmonary infection. A clip was placed on the PDA in 16 patients and PDA was ligated with a 2-0 silk suture in 11 patients. Mean operation time was 18.7 (±5.5) minutes (range, 10–40 minutes). After a day of postoperative follow-up, we sent the patients back to centres they came from. We transferred all the 13 patients back to centres they came from. The remaining patients' postoperative mean mechanical ventilatory support time was 29.5 (±42.6) days (range, 1–165 days), mean hospital stay was 71.5 (±56.0) days (range, 7–193 days) and the mean postoperative length of stay was 47.4 (±44.2) days (range, 6–165 days). There were 8 mortalities after the operation (29,6 %). Five were due to sepsis, one was due to necrotising enterocolitis, one was due to

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Figure 1. Clip ligation of PDA in a 480 g preterm infant.Clip-ligated PDA is shown with black arrow.

hydrops fetalis and one was due to renal failure with hepatoblastoma. There was no internal thoracic artery injury or no need for conversion to thoracotomy or sternotomy. All patients except one were ventilator-dependent before surgery. That patient had rapidly progressive renal failure before the surgery. There were 16 (59%) postoperative complications (8 in Group 1 and 8 in Group 2) during intensive unit care stay. In addition, there were 6 (22%) deaths in the postoperative first 30 days and 4 (14,8%) deaths between the postoperative first month and first year. Two patients died after discharge. The causes of the deaths were sepsis, necrotising enterocolitis, hydrops fetalis, hepatoblastoma and intracranial bleeding. Left diaphragmatic elevation developed in 1 patient, and plication was performed. Three percent (one patient) of all patients needed reoperation because of a significant residual patent ductus arteriosus. This patient was reoperated on postoperative day 1 through the same thoracotomy incision. Other residual shunt closed spontaneously. 17 of all patients are still alive (Table 3).

Discussion

PDA is one of the most common CHDs. Excessive blood flow to the lungs caused by PDA results in pulmonary congestion, pulmonary oedema, and respiratory failure.[10] This patency may also cause cerebral, renal, or mesenteric hypoperfusion that leads to serious complications in ICU.[11] Medical management, surgical ligation, or percutaneous closure of PDA are treatment methods used currently for preterm infants. Percutaneous closure of PDA has really limited place among the treatment methods although transcatheter technology advances.[12–15]

Indomethacin or ibuprofen is used for the medical treatment of PDA. If medical treatment is unsuccessful, surgical closure is performed. These drugs have various side effects and may cause thrombocytopenia, necrotising enterocolitis, pulmonary oedema and bleeding, renal failure.[16] There are even publications suggesting early surgery instead of medical therapy to save the patients from complications of PDA and medications.[17,18]

Rapid development of science and technology new occlusion devices serve to close PDA in appropriately selected preterms. It is still not routinely occluded in very small infants with birth weight ≤ 2 kg and still there is a lack of experience.[12]. However, Pouldar et al reported percutaneous PDA closure with a 3/2 mm Amplatzer Piccolo Occluder Device in a 790 g preterm in their case report. Procedure did not require moving the patients to cardiac catheterisation laboratory or operating room.[19] As it is safe and successful, transcathater closure of PDA receives more attention, but there are some concerns about vascular access, risk of residual shunt, providing the suitable device, possibility of device migration or embolisation and contrast administration in preterm infants.[20,21]

In 1938, Gross was first to ligate PDA successfully.[22] With the improvement in cardiovascular surgery, better cosmetic results and less harm to lung tissue became more important. For this purpose, several minimally invasive techniques have been tried by

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Table 2. Patient characteristics in both groups

	Group 1 (n = 13)	Group 2 (n = 14)	p Value
Sex (male/female)	5/8	4/10	0.586
Gestational age (week)	25.0 ± 1.87	26.7 ± 1.93	0.028*
Mean birth weight (g)	809 ± 167	1229 ± 491	0.007*
Mean age at surgery (days)	23 ± 12	36 ± 20	0.079
Mean weight at surgery (g)	822 ± 169	1528 ± 573	0.000*
Mean PDA size (mm)	2.64 ± 0.61	3.04 ± 0.79	0.162
Preoperative condition			
NEC	2	1	0.496
CHF	13	14	1.000
ARF	6	3	0.173
RDS	12	12	0.586
ROP	2	3	0.686
Sepsis	4	4	0.901
Hydrops fetalis	0	1	0.326
Genetic syndrome	1	0	0.290
Post-resuscitation	0	0	1.000
Failed percutaneous closure	0	0	1.000
Hydrocephalus + tracheostomy	0	1	0.326
Bronchopneumonia	2	3	686
Preoperative MV support	13	12	0.157

NEC: Necrotising enterocolitis, CHF: Congestive heart failure, ARF: Acute renal failure, RDS: Respiratory distress syndrome, ROP: Retinopathy of prematurity, MV: Mechanical ventilation.

surgeons instead of the conventional methods without affecting the operative results.[22,23]

Lateral thoracotomy has been procedure of choice for PDA closure in preterm infants for over five decades, but it doesn't have the qualities that left anterior mini-thoracotomy technique has. Lung injury and potential long-term spinal and chest wall deformities are potential risks of lateral thoracotomy.[24,25]

Verhaegh et al compared lateral thoracotomy with sternotomy for PDA closure in preterm infants, and they found that the postoperative pulmonary complication rate was significantly lower in the median sternotomy patients. This obviously shows that it is important not to touch lungs as much as possible during operation to avoid lung-related postoperative complications.[24]

Technically, left anterior mini-thoracotomy technique requires short surgical times (< 20 minutes), offering direct visualisation of the left recurrent laryngeal nerve, thus preventing complications secondary to its damage, guarantees good surgical exposure of the PDA (also in patients < 1,5 kg who are not routinely managed through catheterisation). In addition, less trauma to lung tissue reduces the risk of pulmonary complications. This technique also has good aesthetical results in early and mid-term follow-up. This is a simple technique and provides good exposure and the closest approach to the PDA when compared to the other thoracotomy incisions. The patient is in the supine position during the operation with the left chest elevated for anterior mini-thoracotomy. Supine position provides extra comfort for the surgeon and can be maintained easily in the operating room or in the ICU. In case of emergency (e.g. massive bleeding), you can easily convert to sternotomy.

We operated all of our patients in the operating room. Patient was under the heater till the beginning of the operation. Sometimes, even gentle traction of pulmonary artery for PDA dissection to have a better view caused bradycardia and hypotension so adrenaline infusion was administered routinely. Our operation time was generally under 20 minutes. Therefore, time under hypothermia was also not long. Our lightest baby was 480 g. Interestingly, we operated twins, two sisters, on the same day and discharged them to home one day apart.

In our study, we especially focused on advantages of the technique on time and lung-related complications and possible surgical complications related to PDA closure. In our cohort, we didn't have any intraoperative bleeding, chylothorax, and chylomediastinum, but we had one left diaphragma elevation. Left diaphragma was plicated, and the patient was successfully discharged. Dissection of PDA for better view may be dangerous for some patients who have more fragile PDA tissue than the others. In these type of cases, we prefer clip ligation. In these cases, using a metallic vascular clip allows for limited dissection and safe occlusion. After the operation air was removed using the underwater drainage system, thoracotomy was closed without placing a chest tube. This may have improved the comfort of the patient after the operation.

48%[13] of the patients were transferred to our centre for PDA closure. After the operation, we followed up the patients for one day in our neonatal ICU. The day after the operation all of the 13 patients were transferred back to their centres. Transfer of a preterm patient especially before the surgery is important. If the patient comes to the surgery in hypothermic condition with loss

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Table 3. Outcome data of both groups

	Group 1 (n = 13)	Group 2 (n = 14)	p Value
Mean total procedure time (min)	18.7 ± 2.1	18.7 ± 7.5	0.980
Mean hospital LOS after surgery (days)	30.0 ± 49.5	20.9 ± 27.3	0.557
Mean postoperative MV time (days)	26.0 ± 45.6	6.7 ± 10.4	0.138
Mean operation time	18.7 ± 2.1	18.7 ± 7.5	0.980
Complications			
Intraoperative death	0	0	1.000
Atelectasis	0	0	1.000
Residual shunt	1	1	0.957
Left recurrent laryngeal nerve injury	0	0	1.000
Chylothorax	0	0	1.000
Pneumothorax	0	0	1.000
Eventration of diaphragm left side	1	0	0.290
Blood transfusions	0	0	1.000
Surgical site complication	0	0	1.000
Transfer to another hospital	6	7	0.842
Complications in the ICU	8	8	0.816
Hospital mortality	6	2	0.070
Still alive	7	10	0.345

MV: Mechanical ventilation, LOS: Length of stay.

of intravenous lines or ventilation problems, this may increase the risk of the surgery.

Although there was no surgery-related mortality, our hospital mortality rate was 29,6 %. This is higher than most of the prior studies related to PDA closure in preterms.[24–26] As our cohort includes preterm patients with PDA and serious comorbidities, these mortality rates are connected to complications associated with prematurity, infection, and comorbidities. Five were due to sepsis, one was due to necrotising enterocolitis, one was due to hydrops fetalis, and one was due to renal failure with hepatoblastoma.

Of course, we have several limitations. First of all, a limited population was retrospectively studied. We only have early and mid-term results but not long-term results. Also, we cannot compare the technique with another technique as we did not have another group operated by another surgical technique. All of these avoid us claiming the superiority of the technique over other techniques. Also, our short- and mid-term results with left anterior mini-thoracotomy technique in preterm infants are promising.

To conclude, left anterior mini-thoracotomy technique can be performed as the first choice when transcatheter intervention cannot be applied in preterm infants. It provides easy access to the PDA, a good exposure, minimal contact with the lungs, good cosmetic results in early and mid-term and shortens the operation time, especially in very low birth weight preterm babies. However, early ligation may be helpful to minimise the complications related to PDA. Prospective randomised studies are needed to compare the technique's safety and efficiency with other conventional techniques.

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Conflicts of interest. None.

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