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Original Article

Phrenic palsy after pediatric cardiac surgery: what is the best modality of management?

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Abstract

Background: Pediatric cardiac surgery is one of the most common causes of diaphragmatic palsy (DP) in infants and young children. The main target in managing a patient with DP is to preserve the respiratory function. Surgical diaphragmatic plication is widely used surgical treatment of DP nowadays especially in infants than in young children. Tracheostomy was suggested also to facilitate the suction of the chest and decrease the pulmonary complications. Thus, the aim of this study was to detect the effect of early intervention to correct the phrenic palsy either by diaphragmatic plication, Tracheostomy or both in pediatric cardiac surgery patients.

Methods: This is a retrospective study on pediatric patients who had cardiac surgical procedures between June 2008 and Dec 2018. There were 3706 patients had been operated at different age groups of whom 42 patients developed DP. The patients were divided into four groups according to type of treatment: Group A for conservative treatment, Group B for diaphragmatic plication only, Group C for tracheostomy only, and Group D for tracheostomy and plication.

Results: The mean age of the studied group was 19.7 ± 23. There was male predominance (78.6 %). Timing of tracheostomy in days was as 30 ±7.1, and 31.8 ±5.4 in group C, and D respectively. Timing of plication was as 10 ±8.3, and 11.1 ±7.6 in group B, and D consequence

Conclusion: The least sepsis recorded for patients with both tracheostomy and DP, delayed surgical intervention led to higher mortality and more sepsis recorded as in conservative technique.

KEYWORDS

Diaphragmatic palsy; Phrenic nerve; Tracheostomy; Pediatric cardiac surgery

Article History

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Introduction

Pediatric cardiac surgery is one of the most common causes of diaphragmatic palsy in infants and young children. This is explained by phrenic nerve injury intraoperatively that may be life-threating condition [1]. Nowadays, there are increasing rate of cases diagnosed with diaphragmatic palsy after congenital heart surgical interference. Clinical presentation of DP includes recurrent pneumonia, inability to wean from ventilator and atelectasis. Contrary children with higher age range had the ability to compensate the loss of diaphragmatic function and usually present with fewer or no symptoms [2].

The main target in managing a patient with DP is to preserve the respiratory function. There is controversy in the proper surgical management of

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DP in children who underwent cardiac surgery. Under prolonged ventilation the plan of dealing with such cases consists of conservative management or surgical interference either by tracheostomy or diaphragmatic plication. Haller et al. suggested a trial of continuous positive airway pressure (CPAP) for 4–6 weeks during which the diaphragmatic function is presumed to improve with conservative management [3, 4].

Surgical diaphragmatic plication is widely used surgical treatment of diaphragmatic palsy (DP) nowadays especially in infants than in young children. Early diaphragmatic plication is one of the main protocols in patients developed DP after univentricular repair. The definitive surgical option in patients with DP is plication of diaphragm. Respiratory status of the children is the main affecting factor in the decision of the diaphragmatic plication [5].

Tracheostomy was suggested also to facilitate the suction of the chest secretions and decrease the pulmonary complications related to prolonged ventilation. This is needed to improve outcomes [6].

The purpose of the work is to detect the effect of early intervention to correct the phrenic palsy either by diaphragmatic plication, Tracheostomy or both in pediatric cardiac surgery patients.

Patients and Methods

This is a retrospective study on pediatric patients who had cardiac surgical procedures between June 2008 and Dec 2018. There were 3706 patients had been operated at different age groups of whom 42 patients developed diaphragmatic palsy. This study was done in the National Heart Institute after the approval of Human Ethics Committee. The main exclusion criteria in our study were the patients who had complicated anomalies besides the cardiac anomalies or who developed untreated chest complications after cardiac surgery. All pediatric patients who had cardiac surgical procedures for cardiac anomalies as: Atrial septal defect, Atrioventricular septal defect, Aortic coarctation, Double Outlet right ventricle, Total anomalous pulmonary venous return, Transposition of great vessels, Ventricular septal defect, Pulmonary stenosis and Ebstien anomalies.

These patients were randomly computerized divided into four groups Group A for patients treated with conservative treatment, Group B for patients treated with diaphragmatic plication only, Group C for Patients treated with tracheostomy only, and Group D for patients treated with both tracheostomy and plication. A written consent was taken from all patients. The diagnosis of diaphragmatic palsy was suspected clinically and confirmed by either fluoroscopy or ultrasonography.

Figure 1 shows chest X-ray with elevation of the left diaphragm after phrenic nerve injury. The routine uses of echocardiographic in the ICU for follow-up facilitated the diagnosis of diaphragmatic palsy. Patients with suspicioun of diaphragmatic paralysis were evaluated by Tran thoracic echocardiography (TTE) with GE Vivid 5 (GE health care, USA). Diagnosis is confirmed by the use of bedside echocardiography while the patient is breathing spontaneously without any positive pressure ventilatory support. On echocardiography, 2 D mode with sub costal view was used to identify diaphragmatic paralysis by Kienböck sign (5), which is paradoxical movement of the diaphragm upward during inspiration and downward during exhalation which is a physical finding in diaphragmatic paralysis. Also paralyzed diaphragm may appear atrophic, with less contraction and shortening during inspiration than that of normal diaphragm by 2 D mode.

Posteroanterior chest radiographs on full inspiration with the patient in the erect position were evaluated in all patients preoperatively. A hemidiaphragm was defined as elevated if its position was two or more intercostal spaces higher than in the preoperative image. The following parameters were recorded postoperatively in all patients: duration of mechanical ventilation/ICU/hospital stay and complications in the ICU (including the need for inotropic support) and until hospital discharge.

All surgical procedures were performed by a single team either tracheostomy or diaphragmatic

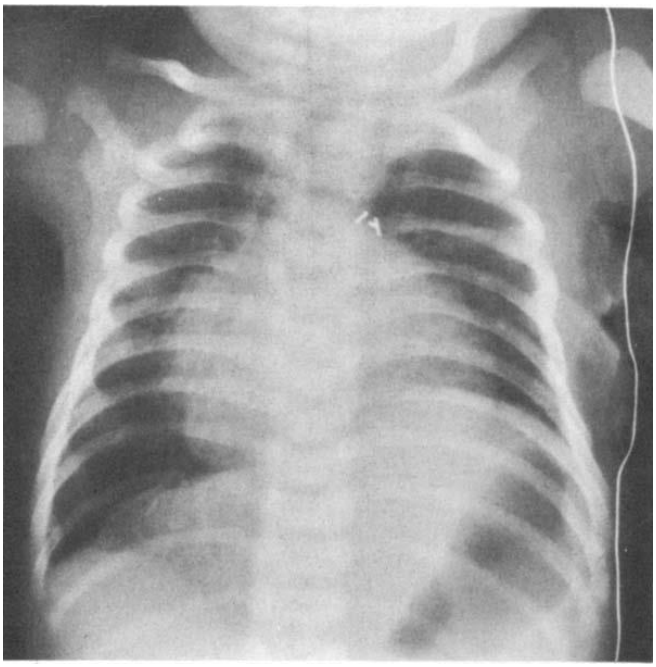

Figure 1: Chest X-ray with elevation of the left hemidiaphragm

plication. Diaphragmatic plications were done using a thoracic approach as described by Cilley and colleagues [7]. In all patients with unilateral paresis the plication was performed through the seventh intercostal space with a lateral thoracotomy and fixation of the diaphragm on the ventral 10th costal arch with non-absorbable braided sutures are placed in a interrupted radial fasion through the diaphragmatic attachments of the thoracic wall, sometimes with pledges. This suture leads to flattening of the diaphragm and give more strength in the diaphragmatic movement. In single cases had bilateral paresis in group B and D, there was only one side plicated similarly. Tracheostomy was done through vertical incision just below the level of the cricoids cartilage followed by dissection of the superficial layers up to the tracheal wall. Then the trachea was opened through superior-based U flap to insert the tracheostomy tube.

Table 1: Patients' characteristics

Parameters	Values	
	Mean ±SD	Range
Age (months)	19.7 ±23	3.5-44
Weight (kg)	9 ±4.5	5.4-12.4
Height (m)	73.2 ±15.3	52.5-91.5
BSA (kg/m)	0.4 ±0.1	0.25-0.55
Gender (Female\Male)	9/33, 21.4%/78.6%	

Statistical analysis:

All mean values are stated ± SD and a probability value less than 0.05 was considered statistically significant. Student-T test and Chi-square test were done using SAS (SAS Procedures Guide, release 6.03 edition; SAS Institute Inc; Cary, NC) software were used for statistical analysis.

Results

The patient characteristics of all included cases are shown in Table 1. The mean age of the studied group was 19.7 ±23 ranging from 3.5-44 months. The mean weight (kg), height (m), body surface area (BSA, kg/m) of the studied patients were 9 ±4.5, 73.2 ±15.3, and 0.4 ±0.1. There was male predominance (78.6 %). The different surgical techniques were discussed in Table 2.

Table 2: Preoperative patients' details

Parameters	No. of DP
Previous diagnosis	
ASD	2
AVSD	5
CoA	1
CoA + DORV	1
DORV	1
Ebstein	1
Single ventricle	8
TAPVD	2
TGA	1
TOF	8
VSD	9
VSD_PS	2
Correction type	
Staged repair	16
Total correction	26
Topical cooling	
Cold saline	15
Ice slush	8
Not applied	19
Technique	
Single ventricle	9
Two ventricles	33

ASD: Atrial septal defect, AVSD: Atrioventricular septal defect, CoA: Aortic coarctation, DORV: Double Outlet right ventricle, TAPVD: Total anomalous pulmonary venous return, TGA: Transposition of great vessels, VSD: Ventricular septal defect, PS: Pulmonary stenosis

Timing of tracheostomy was as 30 ±7.1, and 31.8 ±5.4 in group C, and D respectively. Timing of

plication was as 10 ±8.3, and 11.1 ±7.6 in group B, and D respectively as shown in Table 3. There are significant differences between groups as regard ventilation period and total ICU stay. Table 4 assessed complications occurred and recorded at each group.

Discussion

Diaphragmatic paralysis remains a relatively rare respiratory condition which may be life-threatening in infants and young children. In our retrospective analyses the 6.7% incidence of DP after cardiac surgery is comparable to other retrospective studies that showed an incidence of 0.3–5.7%. In prospective studies the reported incidence varies from 0.5 up to 12.8% which may indicate a substantial number of undiagnosed patients or difficulties in diagnosis [8, 9].

The age of plicated patients was significantly lower compared to the non-plicated. Younger children develop more complications with the DP than the older ones, that could be explained that the younger children depend mainly on diaphragmatic contraction for adequate gas exchange [5].

The intercostal muscles are weaker and there is a more horizontal orientation of the rib cage. In addition, infants have an increased mediastinal mobility with shifting of mediastinal contents to the contra lateral side on inspiration with DP while the paralyzed diaphragm is pulled upwards. On the ipsilateral side, the diaphragm cannot resist negative intra-pleural pressure and moves paradoxically. This reduces functional residual capacity, facilitates alveolar collapse and atelectasis. Moreover, the infants recumbent position leads to a reduction of vital capacity and their small intra-bronchial calibers facilitates obstruction and atelectasis by retained secretions [5].

In earlier years the use of mechanical ventilation was favored as the treatment of choice. Haller et al. suggested a trial of continuous positive airway pressure (CPAP) during 4–6 weeks. This time should allow to differentiate children with respiratory dysfunction from children who will benefit from plication. However, late surgical plication may be jeopardized by atrophy of the diaphragm which may even preclude successful surgical plication [10].

Surgical plication is today the widely accepted treatment of DP especially in children under 1 year of age. However, there is still controversy on its best timing. Some authors recommend that plication should be performed as soon as the diagnosis of DP has been confirmed while others recommend a waiting period of 1–6 weeks in anticipation of potential spontaneous recovery [9, 11].

Regarding the impact of plication on ventilation time and hospital stay, there are reports which describe a reduction after plication. In our study we analyzed the patients retrospectively. For this reason, the groups of plicated and non-plicated patients are not exactly comparable. Although surgical plication of DP improved symptoms in most patients the mortality of patients with DP remained high, due to complex congenital heart disease and complex cardiac surgery [12].

Table 3: Intraoperative and postoperative data

Groups	Timing of Tracheostomy (days)	Timing of placation (days)	Ventilation period (days)	Total ICU stay (days)
Group A (14 cases)	-	-	24.8 ±6.2	29.5 ±4.6
Group B (16 cases)	-	10 ±8.3	15.9 ±8.2	20.6 ±9.1
Group C (7 cases)	30 ±7.1	-	47.9 ±6.0	55.9 ±8.9
Group D (5 cases)	31.8 ±5.4	11.1 ±7.6	39.6 ±7.6	47.6 ±5.9
P-value	0.892	0.785	0.004 S	0.021 S

S: Significant

Table 4: Complications recorded

Groups	Mortality	Positive sputum culture	Positive blood culture	Morbidity (Sepsis)
Group A (14 cases)	9 (64.25%)	8 (57.1%)	3 (21.4%)	8 (57.1%)
Group B (16 cases)	1 (6.25%)	5 (31.2%)	3 (18.7%)	6 (37.5%)
Group C (7 cases)	3 (42.8%)	7 (100%)	0	7 (100%)
Group D (5 cases)	2 (40%)	5 (100%)	2 (40%)	5 (100%)
P-value (Chi-square test)	0.231			

To assess the function of the diaphragm after DP in plicated and non-plicated patients the diaphragmatic position on X-rays and the frequency of pulmonary infections were followed. Using the definition of Greene et al., 86% of surviving plicated patients showed a diaphragm in a normal position 1 month after plication. The return to normal position after plication is also documented in the literature. Pre-disposition to pulmonary infections and pneumonia is a well-known clinical sign of DP. Using the definitions of Cherry and colleagues, that it is 'normal' in infancy to have 3–8 respiratory infections (with no hospital admission required) per year, none of our groups showed a higher pre-disposition to respiratory infections (1.5 infections per year) [13, 14].

Ciccollella et al. explained the physiological success of plication. During inspiration the healthy diaphragm produced negative intrathoracic pressure and the abdominal contents is drawn into the paralyzed side of the thorax. This paradoxical motion does not expand the lung on this side and results in poor gas exchange. After plication the paralyzed side is more resistant again this pressure and the adjacent lung segments expand. The non-plicated patients were mostly older than 12 months so they have better compensatory mechanisms to cope with DP [15].

Prospective studies need to been done with larger sample size to evaluate diaphragmatic function of the plication with or without tracheostomy in these patients including pulmonary function tests at long-term follow-up.

Conclusion

Better results of less mortality and morbidity were discussed at combination of tracheostomy and diaphragmatic plication, thus tracheostomy prevent chest complications till the patient prepared to surgical repair of phrenic nerve injury.

Conflict of interest: Authors declare no conflict of interest.

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