

Diaphragmatic Plication: Retrospective Study with 54 Patients

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ABSTRACT

Objective: This study seeks to evaluate the results of surgery performed according to the etiological causes of diaphragmatic eventration or paralysis. **Method:** Files of 54 patients (35 males, 19 females; mean age: 39.1 ± 3.01 years) who had undergone diaphragm plication between January 2005 and June 2011 in two clinics located in Istanbul were studied in terms of pulmonary spirometry, applied surgical procedure, duration of hospitalization, morbidity, and mortality. **Results:** In diaphragm plications, observed etiologies were isolated diaphragmatic eventration without phrenic nerve injury (Group 1) in 20 (37%) patients due to blunt thoracic trauma; Group 2 (thymoma in 19 (35.2%) patients; lung cancer in 7 (12.9%) patients; mediastinal tumor in 3 (5.6%) patients) and congenital heart surgery (Group 3) in 5 (9.3%) patients. The mean time to plication was 7.4 months in Group 1. The mean duration of hospitalization was 4 days in Group 1, 6.2 days in Group 2, 11.8 days in Group 3. Mean forced vital capacity, forced expiratory volume at 1 second improved by 17%, 20.3%, respectively ($p < 0.005$) in Group 1. In Group 1, mean dyspnea-related hospital admission before plication was 2.4 times. At the end of 6 months after plication mean dyspnea-related hospital admission was 0 time. All of them returned to daily activities or their job within 6 months in Group 1. Postoperative mortality was observed in 2 (3.7%) patients in Group 3 while the overall complication rates were 24%. The morbidity rates were 8%, 27.5%, 60%, respectively; and the mortality rates were 0%, 0%, 40%, respectively. **Conclusion:** As a result, it could be suggested that early and timely performed plications for diaphragmatic eventration improves functional status and assesses a shorter length of stay. On the other hand, simultaneously performed plications in intraoperative phrenic nerve resections can be performed with acceptable morbidity and no mortality. In diaphragmatic paralysis due to congenital heart surgery, morbidity and mortality rate is still high.

Keywords: Diaphragm Plication; Paralysis; Eventration; Phrenic Nerve Resection

1. Introduction

The diaphragm is an anatomical structure consisting of two dome-shaped muscles and an aponeurosis separating the abdomen and the thorax. The main anatomical function of the diaphragm is to separate the thoracic and abdominal cavities; however, its main physiological function is its role in ventilation. Diaphragm is an important muscle as it is involved in 75% of the body's total inhalation activity, and each centimeter of vertical movement contributes to 300 to 400 ml of air during normal breathing [1]. Diaphragmatic eventration or paralysis observed in adults is rarely observed. However, cardiothoracic surgery, mediastinal pathologies, thymus surgery, tumors,

infections, muscle-nerve disease, thoracic and mediastinal radiotherapy, injuries, and granulomatous diseases are the most frequent reasons for diaphragmatic paralysis [2-4]. Paralysis of diaphragm is a severe complication of cardiothoracic surgery carrying significant morbidity and mortality [5]. The aim of the study is to evaluate the results of surgery performed according to the etiological causes of diaphragmatic eventration or paralysis.

2. Patients and Methods

Records of patients that had undergone diaphragm plication for diaphragmatic eventration or paralysis between January 2005 and June 2011 at Istanbul University, Istanbul Medical Faculty, Thoracic Surgery Department and Medicana Hospital's Thoracic Surgery Department

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in Istanbul were studied retrospectively in terms of pulmonary spirometry, applied surgical procedure, duration of hospitalization, morbidity, and mortality and divided into three groups according to etiologies. Fifty-four patients undergoing plication for diaphragmatic eventration or paralysis were included in the study. Thirty-five (64.8%) of these patients were male, and the ages of the patients ranged from 1 to 76 years (Mean age: 39.1 ± 3.01). In diaphragmatic pathologies, the surgical approach differed according to the shape, localization, and status of the lesion. Hence, patients were positioned according to the surgical approach to be performed. In mediastinal lesions, sternotomy was performed under general anesthesia, while diaphragm plication was performed during single lung ventilation by right or left mini-lateral thoracotomy through the 8th intercostal space and by bilateral mini-lateral thoracotomy through the 8th intercostal space in those having a history of congenital heart surgery.

Respiratory function test and fluoroscopic sniff test were performed before surgery in patients thought to have primary pathology of diaphragm. Radiographically, two-way plain radiographies were obtained for all the patients while computed tomography was obtained when deemed necessary. Surgically, diaphragm plication was generally performed starting from the mediasten with monofilament 1/0 non-absorbable sutures passing from posterior to anterior and protecting the organs beneath the diaphragm by lifting the diaphragm with a clamp or by phrenotomy (**Figure 1**). In general, 5 - 8 successive sutures were sufficient for a diaphragm plication, and a mesh could support a delicate diaphragm.

Statistics

Continuous data are expressed as the mean plus or minus the standard deviation of the mean except where otherwise indicated. Differences between categorical variables were evaluated by Fisher's exact test. Differences be-

tween continuous variables were measured by the two-tailed Student test. Statistical significance was accepted as p less than 0.05.

3. Results

For the diaphragm plications, the observed etiologies were isolated diaphragmatic eventration without phrenic nerve injury (Group 1) in 20 (37%) patients; Group 2, $n = 29$ (thymoma in 19 (35.2%) patients; lung cancer in 7 (12.9%) patients; mediastinal germ cell tumor in 3 (5.6%) patients) and congenital heart surgery in 5 (9.3%) patients (Group 3), (**Figure 2**). Thirty-four (63%) of the diaphragm plications resulted from resection due to invasion of the phrenic nerve by tumor or from damage due to congenital heart surgery. Surgically, a right thoracotomy was performed in 12 (22.2%) patients, left thoracotomy in 27 (50.0%) patients, bilateral thoracotomy in 5 (9.3%) patients, and a sternotomy was performed in 10 (18.5%) patients (**Table 1**).

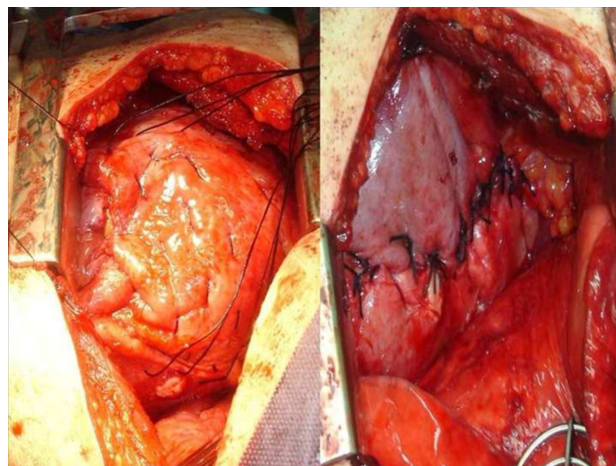


Figure 1. Photographic views of diaphragm eventration with intraoperative sutures and diaphragm plication.

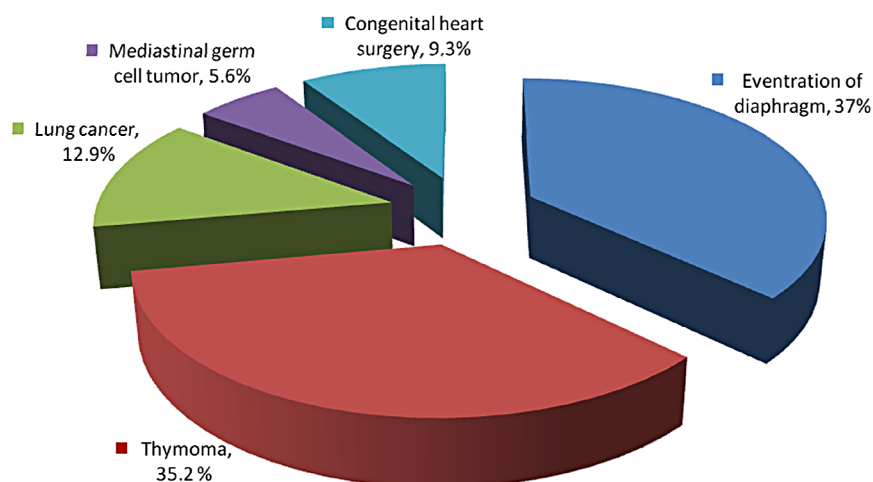


Figure 2. Etiological reasons in diaphragm plication.

Table 1. Surgical procedures in diaphragm plication.

	Number of patients	Right thoracotomy (%)	Left thoracotomy (%)	Bilateral thoracotomy (%)	Sternotomy (%)
Eventration of diaphragm	20	4 (20)	16 (80)	-	-
Thymoma	19	3 (15.8)	7 (36.8)	-	9 (47.4)
Causes related to phrenic nerve resection or injury	7	4 (57.1)	3 (42.9)	-	-
Lung cancer	3	1 (33.3)	1 (33.3)	-	1 (33.3)
Mediastinel germ cell tumor	5	-	-	5 (100)	-
Congenital heart surgery	5	-	-	5 (100)	-
TOTAL	54	12 (22.2)	27 (50.0)	5 (9.3)	10 (18.5)

The mean time to plication was 7.4 months in Group 1. The mean duration of hospitalization was 4 days in Group 1, 6.2 days in Group 2, 11.8 days in Group 3. Mean forced vital capacity, forced expiratory volume at 1 second improved by 17%, 20.3%, respectively ($p < 0.005$) in Group 1 (**Table 2**). In group 1, mean dyspnea-related hospital admission before plication was 2.4 times. At the end of 6 months after plication mean dyspnea-related hospital admissions were 0 time. All of them returned to daily activities or their job within 6 months in Group 1 (**Table 2**). Postoperative mortality was observed in 2 (3.7%) patients in Group 3 while the overall complication rates were 24% (**Table 3**).

4. Discussion

Although etiologies of diaphragmatic eventration and paralysis are different, their treatments are the same. Diaphragmatic eventration is the most frequently encountered primary pathology of the diaphragm. Diaphragmatic eventration is a clinic situation characterized by relocalization of the abdominal viscera into the thorax. While it is observed particularly at pediatric age, it is encountered rarely in adults. Generally, it is right sided and asymptomatic [1]. The most frequently reported causes of acquired diaphragmatic eventration are previous intrathorax surgery or trauma [6]. Most of times, treatment is not necessary in diaphragmatic eventration. However, treatment is applied when there are symptoms, such as respiratory distress, poor exercise tolerance, recurrent pneumonia, chronic bronchitis, cardiac arrhythmia, and functional gastric disorders [6,7]. In the current study, diaphragm plication was found to have been performed in 20 (37%) patients due to diaphragmatic eventration. Four of these patients had a right mini-lateral thoracotomy, while 16 had a left mini-lateral thoracotomy through the 8th intercostal space. The aim of plication is to increase lung compliance on the concerned side, decrease paradoxical movement, and to make the mediastinum more stable by flattening the eventrated hemidiaphragm [8,9]. Some authors have reported that a respiratory function test when standing or at rest, a fluoroscopic sniff-test to observe paradoxical movement of diaphragm, or an ultrasonography are sufficient and no other examinations

Table 2. Functional status at six month follow up for patients treated with diaphragm plication in Group 1(n = 20).

Pulmonary function tests	Mean changes in percent for each parameter
Forced expiratory volume at 1second	+17%
Forced vital capacity	+20.3%
Return to daily activities	+20
Dyspnea-related hospital readmission	0

are required [10,11]. In the current study, a respiratory function test and fluoroscopic sniff-test were found to have been performed in patients thought to have isolated diaphragm eventration. In our previous study [12] analyzing long term (32.9 months on average) respiratory function tests of 11 patients undergoing unilateral diaphragm plication found that spirometric findings improved significantly after plication. In current study, significant improvements for forced expiratory volume at 1 second and forced vital capacity were seen in Group 1. Additional examinations were performed only in patients with suspected pathologies due to tumors with phrenic nerve involvement. While in diaphragmatic paralysis in infants and young children there is consensus about early plication, in adults there is less uniformity about the timing of surgical plication that is usually suggested and applied at a later time [13]. In our study, the mean time to plication was 7.4 months in Group 1. Our current experience, opposite the previous study [12], we advocate that long waiting period in certain patients for plication can cause more perioperative complications.

Thymoma, arising from thymic epithelial cells and associated with non-neoplastic T lymphocytes to varying degrees, is the most common tumor of anterior mediastinum. In our study, diaphragm plication was performed due to phrenic nerve resection in 19 (35.2%) patients having phrenic nerve involvement of thymoma. It has been advocated that a complete resection is the most appropriate treatment choice in determining long-term survival [14,15].

Lung and mediastinal cancers may affect the diaphragm by invading the phrenic nerve. In the current study, diaphragm plication was performed due to phrenic nerve resection in 7 (12.9%) patients with phrenic nerve involvement of lung cancer. Mediastinal germ cell tumors are aggressive, and they frequently invade the phrenic

Table 3. Complication rates in terms of diagnosis in diaphragm plications.

	Number of patients	Mortality	Complications								
			None	Atelectasis	Respiratory failure	Bleeding	Ileus	Wound infection	Pneumonia	Chylothorax	Prolonged air leak
Eventration of diaphragm	20	-	18	-	1	-	1	-	-	-	-
Thymoma	19	-	13	1	1	1	-	1	1	1	-
Lung cancer	7	-	7	-	-	-	-	-	-	-	-
Mediastinal germ cell tumor	3	-	1	-	-	1	-	-	-	-	1
Congenital heart surgery	5	2	-	-	3	-	-	-	-	-	-
TOTAL (%)	54	2 (3.7)	39 (72.1)	1 (1.9)	5 (9.3)	2 (3.7)	1 (1.9)	1 (1.9)	1 (1.9)	1 (1.9)	1 (1.9)

nerve. In the current study, diaphragm plication was found to have been performed due to phrenic nerve resection in 3 (5.6%) patients having phrenic nerve involvement due to mediastinal germ cell tumor. In the surgical procedure, phrenic nerve resection leads to hemi-diaphragmatic paralysis whether it is right-sided or left-sided. For this reason, vital capacity is reduced by 20% to 30% [1]. While this does not generally cause a respiratory difficulty in normal adults, severe respiratory difficulty is observed in elder patients (over 80 years old) having severe myasthenia gravis, myotonic dystrophy, or chronic obstructive pulmonary disease. Hence, bilateral phrenic nerve resections especially should be avoided. In their study, Yano *et al.* [16] reported how patients having phrenic nerve invasion should be handled, and that a combined resection improved treatment but phrenic nerve resection could have a deteriorating effect on post-operative life quality and cause various complications in Masaoka stage 3 thymoma. However, they reported that preservation of the involved phrenic nerve may affect the survival of thymoma patients negatively, but no patients undergoing phrenic nerve resection due to phrenic nerve invasion died during intraoperative or postoperative periods, and one patient died of chronic respiratory failure 29 months after the operation. In our study, morbidity rate was 27.5% and no mortality in Group 2.

Tokunaga *et al.* [17] performed intraoperative unilateral diaphragm plication in 13 patients (6 with lung cancer, 6 with mediastinal tumor, and 1 with mesothelioma) undergoing phrenicotomy to prevent postoperative complications. A year after the operation, 10 (77%) patients had no postoperative complications, 3 (23%) had pulmonary complications, and 2 (15%) required prolonged mechanical ventilation. They also reported that postoperative lung function after plication was similar to predicted postoperative lung function, and that diaphragm plication was effective to prevent postoperative pulmonary complications and to preserve postoperative lung function in such patients.

In a review on etiology, pathophysiology, diagnosis,

and treatment of diaphragmatic eventration and paralysis in adults, Shawn *et al.* [18] reported that diaphragm plication was only indicated for symptomatic patients with diaphragmatic paralysis or eventration. They also reported that there was a variety of open and minimally invasive transthoracic and transabdominal techniques and that the short-term outcomes after minimally invasive plication were promising but long-term results had yet to be published. So, it could be suggested that minimally invasive techniques may be more adequate in isolated diaphragmatic eventrations.

Following congenital heart surgery, diaphragmatic paralysis may be observed due to phrenic nerve injury. Nearly 64% of the diaphragmatic paralysis occurring in cardiovascular surgery resulted from phrenic nerve injury. The incidence of diaphragmatic paralysis after pediatric cardiac surgery has been reported as 0.28% - 5.4% [19]. In 100 patients (50 infants and 50 children) under 15 years old, Mok *et al.* [20] found the incidence of diaphragmatic paralysis as 10% by preoperative and post-operative (within 72 hours of operation) transcutaneous phrenic nerve stimulation. In the current study, bilateral mini-thoracotomy and diaphragmatic plication were performed in the same session in 5 (9.3%) pediatric patients having bilateral diaphragmatic paralysis following congenital heart surgery.

In the current study, no complications were observed in 39 (72.2%) patients. Respiratory failure was observed in 5 (9.3%) patients, while 3 of these patients were those undergoing bilateral diaphragmatic plication after congenital heart surgery. Postoperative hemorrhage was seen in 2 (3.7%) patients with thymoma and mediastinal germ cell. Atelectasis, ileus, wound infection, pneumonia, chylothorax, and prolonged air leak were each observed in different individual patients. Mortality was observed in 2 (3.7%) patients undergoing diaphragmatic plication following congenital heart surgery and requiring postoperative ventilator dependency and close follow up. In this patients, morbidity, mortality, and complication ratios were significantly higher compared to those in others.

There is almost always failure to wean for mechanical ventilation in infants and young children with diaphragmatic paralysis after cardiac surgery. El Tantawy *et al.* [21] reported that patients with diaphragmatic paralysis had significantly prolonged ventilation duration, higher incidence of pneumonia, longer duration of intensive care unit, and mortality as compared to unaffected patients. They also reported that early plication for certain patients may lead to improved outcomes.

As a result, we suggest that early and timely performed plications for diaphragmatic eventration improves functional status and assesses a shorter length of stay. On the other hand, simultaneously performed plications in intra-operative phrenic nerve resections can be performed with acceptable morbidity and no mortality. In diaphragmatic paralysis and plication due to congenital heart surgery, morbidity and mortality rate is still high.

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