

## Cardiac Herniation Following Intrapericardial Pneumonectomy with Partial Pericardiectomy for Advanced Lung Cancer

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**We present in this paper a case of cardiac herniation following right intrapericardial pneumonectomy after induction chemotherapy. A 52-year-old man with advanced squamous cell carcinoma of the lung was admitted to our hospital suffering from a dry cough and chest pain. An intrapericardial pneumonectomy with partial pericardiectomy (4×4 cm) was performed. The pericardial defect was left open. Just prior to removal of the tracheal tube, cardiac herniation occurred with hypotension, arrhythmia and cardiac arrest. A chest X-ray revealed cardiac herniation into the right hemithorax. Re-thoracotomy was performed and the heart was returned to its normal position and the pericardial defect was immediately repaired with an expanded polytetrafluoroethylene (EPTFE) patch. The patient's postoperative course was uneventful. Unless prompt diagnosis and surgical treatment can be accomplished, cardiac herniation can be a fatal complication. We recommend that when pneumonectomy is performed, pericardial defects should be closed with a prosthetic patch, regardless of the defect's size. (Ann Thorac Cardiovasc Surg 2003; 9: 68–72)**

**Key words:** cardiac herniation, intrapericardial pneumonectomy, lung cancer, pericardiectomy

### Introduction

Cardiac herniation occurring after surgery for lung cancer involving pericardiectomy or pericardiectomy was first reported in 1948 by Bettman et al.<sup>1)</sup> Although this complication, which begins with symptoms of severe shock, is rare, it can be fatal if treatment is delayed. For this reason, surgeons are becoming more aware of the necessity of early diagnosis and treatment of this complication. Radical surgery, involving intrapericardial pneumonectomy and pericardiectomy, is now being performed with increasing frequency for the treatment of lung cancer. For this reason, reports of patients developing cardiac herniation following surgery for lung cancer are not

uncommon.

At our facility, a patient with advanced lung cancer, accompanied by mediastinal invasion, was treated by right intrapericardial pneumonectomy with partial pericardiectomy. Immediately after surgery, the patient developed cardiac herniation and fell into shock. Re-thoracotomy was performed to return the herniated heart to its original position and to completely close the pericardial defect with a patch, thus saving the life of the patient. This case will be presented in this paper, with references to the literature.

### Case Report

The patient, a 52-year-old man, first showed symptoms in the autumn of 2000 when he developed a cough. In March 2001, the cough was also accompanied by chest pain. He therefore consulted a nearby clinic. A chest X-ray led to the diagnosis of atelectasis of the right upper lobe and advanced lung cancer with mediastinal invasion. The tumor was diagnosed as squamous cell carcinoma as a result of histological examination of a specimen ob-

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**Fig. 1.** Chest X-ray reveals a mass, 8 cm in diameter, located in the hilus of the right upper lobe. The right upper bronchus is obstructed, causing atelectasis. The right upper lobe appears to be occupied almost completely by tumor.

tained by bronchoscopic biopsy. Because the mediastinal invasion by the tumor was severe, the patient's condition was judged to be inoperable, and he therefore received two courses of chemotherapy, consisting of cisplatin (CDDP) and vindesine (VDS). However, the therapeutic effect was rated as no change (NC). In September 2001, the patient visited our department. He was a heavy smoker, with a smoking index (average number of cigarettes per day × years of smoking history) of 1,800 (60/day × 30 years). Urinalysis and blood biochemistry revealed no noteworthy findings. Of the serum tumor markers tested, carcinoembryonic antigen (CEA) was 1.5 ng/ml (range: 0-2.5 ng/ml), squamous cell carcinoma antigen (SCC) was 1.1 ng/ml (range: 0-1.5 ng/ml) and neuron-specific enolase (NSE) was 36 ng/ml (range: 0-10 ng/ml). Thus only NSE was higher than normal. On chest X-ray (Fig. 1), a tumor, 8 cm in diameter, was detected in the hilus of the right upper lobe, and the right upper lobe bronchi were obstructed, causing atelectasis. The right upper lobe appeared to be almost fully occupied by the tumor. Chest computed tomographic (CT) scans (Fig. 2) also revealed that the right upper lobe was occupied almost completely by the tumor. It seemed quite likely that the tumor had invaded the right main pulmonary artery (m-PA) and the right upper pulmonary vein



**Fig. 2.** Chest CT scans reveal that the right upper lobe is occupied almost completely by tumor. Tumor invasion into the right m-PA and the right u-PV is strongly suggested. The SVC is narrowed but remains patent. No significant swelling of mediastinal lymph nodes is visible.

(u-PV). The superior vena cava (SVC) seemed narrow but remained patent. No significant swelling of the mediastinal lymph nodes was seen. Bronchoscopy (BF) revealed an exposed tumor in the right upper bronchus, which had obstructed the orifice completely. Brain CT scans, abdominal CT scans, bone scintigraphy, Ga scintigraphy and other diagnostic imaging methods revealed no signs of distant metastases. The results of a respiratory function test were favorable as follows: vital capacity (VC), 4.20 L; %VC, 116.7%; forced expiratory volume in 1 second (FEV<sub>1.0</sub>), 3.30 L; FEV<sub>1.0</sub>%, 78.6%. An arterial blood gas analysis showed normal findings as follows: pH, 7.442; arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>), 43.2 mmHg; arterial partial pressure of oxygen (PaO<sub>2</sub>), 87.8 mmHg; base excess (BE), 3.8 mmol/L.

On the basis of these findings, the patient was diag-



**Fig. 3.** Postoperative chest X-ray showing a shift of the cardiac shadow into the right hemithorax.



**Fig. 4.** Chest X-ray immediately after re-thoracotomy showing that the heart has returned to the normal position.

nosed as having squamous cell carcinoma originating from the right upper lobe of the lung with mediastinal invasion. We judged that the tumor could be treated by intrapericardial pneumonectomy (combined with SVC resection and reconstruction if tumor invasion into the SVC was positive). We performed the surgery on September 25, 2001. A thoracotomy was performed through a median sternotomy, followed by skin incision into the anterior chest wall, extending from the midline to the right posterior axillary line. Then, the anterior part of the pericardium was vertically opened to detect whether or not invasion of the intrapericardial structure was present. Once resection had been considered feasible, the operating table was rotated to elevate the right hemithorax. Within the pericardial cavity, the right m-PA and the right u-PV were manipulated using a surgical stapler. Because the cancer had invaded the right lateral part of the pericardium, the portion of the pericardium near the SVC and right main bronchus were resected (4×4 cm). Another vertical incision was made around the right lower PV (l-PV), followed by manipulation of the right l-PV within the pericardial cavity using the stapler. Then, the right main bronchus was manipulated using a stapler to complete right pneumonectomy (No direct tumor invasion into the SVC was detected). The initial vertical incision of the pericardium was closed by continuous suture. The latter vertical incision of the right lateral part of pericardium was closed with a 1 mm thick expanded polytetrafluoroethylene (EPTFE) patch, and the upper defect was left open, since the possibility of cardiac herniation was considered to be

low. A water-sealed thoracic drain was inserted. The cleft in the sternum was closed with 5 pieces of No.5 Ethibond (non-absorbable suture), while the intercostal space was closed with No.2 Vicryl (absorbable suture). Thus, the operative procedures were completed.

The patient's posture was then changed to the supine position to begin aspiration of sputum through the tracheal tube (the patient demonstrated cough reflex during this procedure). Immediately before the tracheal tube was withdrawn, the patient suddenly developed tachycardia, arrhythmias and hypotension. Then bradycardia developed, leading to cardiac arrest. The patient was immediately resuscitated by extracorporeal heart massage. At the same time, cardiac herniation into the right thoracic cavity was detected on chest X-ray (Fig. 3). Therefore, re-thoracotomy was performed. The heart had completely prolapsed into the right thoracic cavity and had twisted by about 120 degrees counter-clockwise. The heart was returned to its original position through the open part of the pericardium without difficulty (Fig. 4). The arrhythmia disappeared and blood pressure stabilized following the return of the heart to its original position. No abnormalities were detected in the suturing of the patch-covered area of the pericardium. However, since the pericardial defect had expanded to 7×5 cm, an additional patch was applied to this area to completely close the pericardium. The tracheal tube was withdrawn immediately after re-operation. The postoperative course was uneventful. After receiving two courses of adjuvant chemotherapy using CDDP and vinorelbine (VNB), the patient was dis-

charged 72 days postoperatively. At present, 12 months after surgery, the patient is doing well without any sign of recurrence. The removed tumor was histologically diagnosed as a poorly differentiated squamous cell carcinoma, 8 cm in diameter. The tumor had grown beyond the right upper bronchus and was exposed on the right main bronchus. Cancer had invaded the pericardium and the intrapericardial PA, but the surgical margins were all tumor negative. No metastases were detected in the dissected lymph nodes.

## Discussion

As the number of patients with primary lung cancer has increased, intrapericardial pneumonectomy or pneumonectomy combined with partial pericardiectomy has been performed on an increasing number of patients. Cardiac herniation can occur, although rarely, after lung cancer surgery involving pericardiotomy or pericardiectomy. The first such case was reported in 1948 by Bettman et al.<sup>1)</sup> In 1999, Kimura et al.<sup>2)</sup> reviewed 68 reported cases of cardiac herniation following lung surgery. They reported that cardiac herniation was more frequent on the right side (46 cases) than on the left side (22 cases) and proved fatal in 12 patients with right side herniation and nine with left side herniation.

The symptoms of cardiac herniation are related to the location of the pericardial defect created by cardiac dislocation. On the right side, obstructive shock induces kinking or torsion of both SVC and the inferior vena cava (IVC), with subsequent reduction of cardiac filling. This can result in a decrease in systemic blood pressure, a sharp rise of central venous pressure and the onset of tachycardia.<sup>3)</sup> On the left side, cardiac herniation produces dysrhythmias and myocardial ischemia due to compression or strangulation of the ventricular wall by the pericardial edges, which can lead to hypotension, ventricular fibrillation and infarction.<sup>4)</sup>

Most cases of cardiac herniation developed after pneumonectomy. In some cases, however, it has also developed after lobectomy.<sup>5)</sup> In 75% of the reported cases, it occurred before the end of the surgery, i.e., during repositioning of the patient.<sup>6)</sup> The lack of reported cases of late herniation (more than 24 hours postoperatively) is probably the result of rapid development of adhesions between the heart and the pericardium.<sup>7)</sup>

Factors which can trigger cardiac herniation include coughing, positive pressure ventilation, suction on the chest drains, or re-positioning of the patient with the op-

erated side downwards.<sup>8)</sup> A leading factor which triggers cardiac herniation after pneumonectomy is a rise in the thoracic pressure due to coughing (reportedly reaching over 100 mmHg), which probably pushes the heart towards the side that has been operated upon. It is plausible to imagine that in the presence of a pericardial defect, coughing is likely to elevate the thoracic pressure, which pushes the heart towards the defect, possibly leading to cardiac herniation. Particularly in patients who have undergone pneumonectomy, the pericardium on the operated side will be directly affected by a sudden elevation in thoracic pressure. A pericardial incision that has been closed by suturing can open again during coughing, sometimes to the extent that it causes cardiac herniation. In fact, many of the patients whose pericardium was sutured directly developed cardiac herniation. In the present case, the onset of cardiac herniation seemed to be triggered by the following factors in addition to the presence of a pericardial defect: (1) postural change to the supine position after surgery, (2) decompression of the thoracic cavity on the operated side, using a water-sealed thoracic drain, and (3) elevation of the thoracic pressure due to cough reflex during sputum aspiration.

Treatment is directed at immediate replacement of the heart to its normal position and closure of the defect by one of several methods. Although Bettman et al.<sup>1)</sup> recommended enlarging or excising the pericardium, it has been recognized that this will not prevent cardiac herniation. Cardiac herniation was seen even in cases where the pericardium was closed by suturing. We may therefore say that direct closure of the pericardium with sutures does not always prevent cardiac herniation. When the pericardium is closed by suturing, it is often sutured loosely to avoid postoperative cardiac tamponade. Such loose suturing can also trigger cardiac herniation. Although a method by which the pericardial edge is directly sutured to the myocardium has been reported,<sup>9)</sup> this can injure the myocardium.

Since the 1970s, patch closure has often been used for the treatment of cardiac herniation. To our knowledge, there have been no reports of recurrence of herniation after this treatment. Materials used to fill the pericardial defect include the patient's own tissue (fascia lata, pleural flaps, and so on) and artificial materials such as Teflon grafts or EPTFE patches. Fascia lata is widely used in plastic surgery on various sites. Its strength is satisfactory, but it has the disadvantage of creating a wound in another area besides the chest.<sup>10)</sup> Pleural flaps are easy to harvest and can be obtained in only a few minutes, but

their strength is insufficient. Teflon grafts have no problem with regard to strength. However, since Teflon is polyporous, fibrous tissue hyperplasia can cause complication by constrictive pericarditis or infection. On the other hand, because of the appropriate strength, simplicity, and the low risk of infection, EPTFE patches are often used. Considering that the patient in the present case developed cardiac herniation even though his pericardial defect was only about 4×4 cm, it seems worth recommending that in patients with a pericardial defect who undergo pneumonectomy, the defect is closed with a patch to reduce the pericardial tension even when the defect is small. In view of the quite poor prognosis of cardiac herniation, it seems essential to avoid direct suturing which can increase tissue tension, whenever possible, and to prevent cardiac herniation by patch closure.

We have used an anterior approach in the operation for cases of T4 lung cancer, which had invaded the mediastinal structure. With this approach, the surgeon can have a direct view of both intrapericardial and intrathoracic structures at the same time. A good view of the operative field makes surgical manipulations safer and simpler. Another advantage of this approach lies in that blood loss during surgery can be minimized by first manipulating the great vessels of the lung within the intrapericardial space. On the other hand, approaches involving standard posterolateral thoracotomy often make manipulation of the great vessels of lungs difficult, since these vessels are located most deeply and the main tumor often invades the mediastinal structure. For these reasons, we selected the anterior approach in the present case.

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