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CASE REPORT

Case report of cardiac herniation after sleeve pneumonectomy with superior vena cava reconstruction

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Abstract
Cardiac herniation is a complication that occurs after intrapericardial pneumonectomy. It is life-threatening unless promptly diagnosed and surgery performed. We report a case of cardiac herniation after right intrapericardial pneumonectomy following radiotherapy for lung cancer. The patient developed cardiac herniation with sudden hypotension following a switch to the spine position. An immediate switch to the lateral decubitus position improved the cardiocirculatory dynamics, and surgical patch closure was performed. The circulation dynamics was unstable for several hours after surgery with elevated enzyme levels, which improved 2 days later. Immediate thoracotomy before irreversible myocardial damage resulted in a successful outcome. The risk of cardiac herniation should always be considered after intrapericardial pneumonectomy.

Keywords Cardiac herniation · Post pneumonectomy · Intrapericardial pneumonectomy

Introduction

Cardiac herniation induced by a pericardial defect after intrapericardial pneumonectomy is a known fatal complication. Hence, the mortality of cardiac herniation is 100% in unrecognized cases; prevention and early diagnosis are very important. There have been several case reports describing the trigger, first symptom, and clinical course since it was first reported by Bettman et al. [1].

Here we present a typical case of cardiac herniation after intrapericardial right pneumonectomy and review the clinical characteristics from the past literature.

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Case

A 65-year-old man with stage IIIB (T4N2M0) primary lung cancer (squamous cell carcinoma) (Fig. 1) underwent radiotherapy where the primary lesion and mediastinum were exposed to 39 Gy. There was no change in tumor size and therefore surgical resection was opted for. He had no history of cardiovascular disease.

The surgery was performed in the left lateral position. Right sleeve pneumonectomy and resection of the superior vena cava (SVC) with pericardial resection were performed. Revascularization was performed using a 10-mm ePTFE graft for the left innominate vein and a 16-mm ePTFE graft for SVC. The pericardial defect measured approximately 6 × 7 cm. A 0.1-mm PTFE membrane was used for the pericardial closure by continuous sutures with 3-0 non absorbable monofilament strings. A 24-Fr tube drain was inserted and clamped during the procedure.

The chest tube was suctioned to check the intrapleural pressure and pleural effusion status after switching the patient to the supine position in the operation room. The patient developed sudden hypotension. A chest roentgenogram revealed cardiac herniation and torsion (Fig. 2a). The position of the patient was switched to left side down as soon as the chest roentgenogram was checked. Though

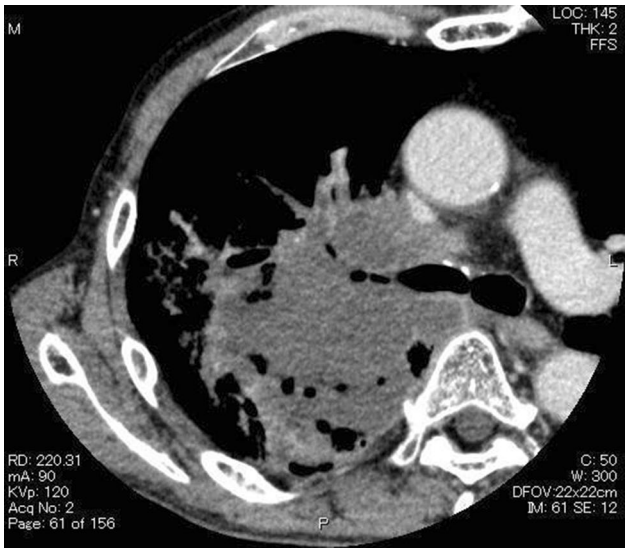


Fig. 1 CT revealed a 10-cm mass around the right main bronchus, and invasion to the superior vena cava was suspected. The paratracheal lymph node was swollen

it took about 5 min, this simple maneuver improved the hemodynamic parameters.

Rethoracotomy was performed immediately. A cardiac herniation induced by a pericardial window due to a tear of the pericardium subsequent to the application of a pericardial patch slipped down to the apical position (Fig. 2b).

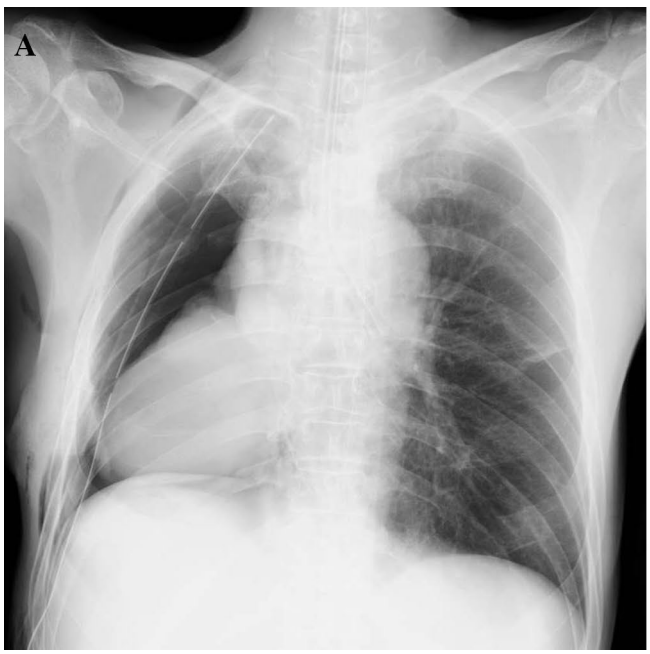
Patch closure was performed by stapling two membranes and that resulted in successful correction of the heart position.

The patient was turned over to the intensive care unit (ICU). His cardiovascular status gave rise to little anxiety for several hours. Systolic blood pressure and heart rate ranged from 70 to 120 mmHg and 50 to 100 bpm, respectively. Creatine kinase MB (CK-MB) rose to 28 IU/L. Chest X-ray showed no findings of hemothorax and cardiac herniation. UCG revealed no findings of a synergy. Clinical state improved gradually and the CK-MB fraction normalized within 2 days (19 U/L). These events may have been due to reversible damage of the atrial junction when the superior vena cava and pulmonary artery were twisted. The patient was discharged on day 7 postoperative with no symptoms.

Discussion

Intrapericardial pneumonectomy must be performed for complete resection in some cases of central advanced lung cancer. No significant difference was reported regarding operative morbidity between standard and intrapericardial pneumonectomies, however, the rate was high for both (morbidity rate 13.4% and 18.5%) [2].

Cardiac herniation is a fatal complication that occurs after intrapericardial pneumonectomy. The typical onset is sudden hypotension within 24 h after surgery triggered by fluctuations in intrathoracic pressure from cough, drainage,



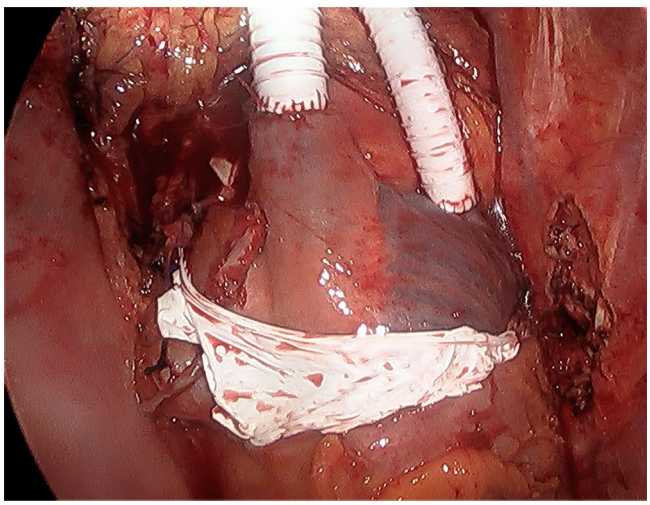


Fig. 2 **a** Chest roentgenogram revealed cardiac herniation and torsion. **b** This picture shows findings of the rethoracotomy. The pericardial patch that covers the defect of the right pericardium slipped due to a tear of the original pericardium

Table 1 Review of the literature of cardiac herniation

Age	Sex	Author	Literature		Side	Onset (postope.)	Symptom	Therapy	Outcome
1	53 M	Bettman	Ann Surg	1948	L	Immediately	Hypotension, cyanosis	Pericardiotomy	Recovery
2	41 M	Kirchhoff	Anaesthesiology	1951	R	Immediately	Hypotension, SVC synd	Pericardiotomy	Recovery
3	M	Higginson	J Thorac Surg	1953	R	Immediately	Hypotension	Pericardiotomy	Recovery
4	M				R	24 h	Asymptomatic	Pericardiotomy	Recovery
5	M				R	Immediately	Hypotension	Pericardiotomy	Recovery
6	M				R	8 h	Hypotension, SVC synd	None	Death
7	69 M	Dahlback	Acta Chir Scand	1956	R	Immediately	Hypotension, cyanosis	Suture	Recovery
8	53 M	Neville	Am J Surg	1954	L	1 h	Hypotension, SVC synd	Suture	Recovery
9		KU YC	Chinese med J	1959	R	Immediately	Hypotension	Pericardiotomy	Recurrence
10	66 M	Sharma	Thorax	1959	L	Recovery room	Hypotension, precordialgia	None	Death
11	31 M				L	Recovery room	Precordialgia	Pericardiotomy	Death
12	40 M	Walmsley	Lancet	1645	L	15 min	Hypotension, cyanosis	Pericardiotomy	Recovery
13	54 M	Gravel	Can J Surg	1966	R	Arrival on ward	Hypotension, SVC synd	Patch closure	Death
14	59 M				L	4 h	Hypotension, SVC synd	Pericardiotomy	Death
15	67 M	Yacoub	Thorax	1968	L	Arrival on ward	Hypotension, varicosis	Patch closure	Death
16	72 M				L	12 h	Hypotension, LBBBB	Patch closure	Death
17	51 F	Gates	Radiology	1970	R	Arrival on ward	Hypotension, SVC synd	Patch closure	Recovery
18	58 M	Takita	Cardiovasc Surg	1970	L	Immediately	Hypotension, SVC synd	Direct suture	Death
19	37 M	Wright	Thorax	1970	L	Same day	Hypotension, varicosis	Pericardiotomy	Recovery
20		Konrad	Thoraxchir Vasc Chir	1971	R	6 h	Hypotension, dyspnea	Patch closure	Recovery
21	20 M	Mckleen	Anesth Analg	1972	R	Immediately	Hypotension, varicosis	Direct suture	Recovery
22	53 F	Levin	JTCVS	1971	R	Arrival on ward	Hypotension, varicosis	Direct suture	Death
23	58 M	Dippel	JTCVS	1973	L	Recovery room	Hypotension, varicosis	None	Death
24	20 M				R	Recovery room	Hypotension		Recovery
25	57 M	Patel	JTCVS	1973	R	30 min	Hypotension, abnor-MCG	None	Death
26	53 M	Deiraniya	Thorax	1974	R	30 min	Hypotension, bleeding	Repair the tear	Death
27	72 F				L	16 h	Hypotension, bradycardia	Patch closure	Recovery
28	65 M				R	2 h	Hypotension, haematoma	Patch closure	Death
29	28 M	Tsuchiya	Japanese	1976	R	2.5 h	Hypotension	Patch closure	Recovery
30		Konrad	Helv Chir Acta	1976	R	Immediately	Asymptomatic	Patch closure	Recovery
31					R	4 h	Hypotension, varicosis	None	Death
32		Baltrami	Acta Chir Belg	1977	R	Immediately	Hypotension, varicosis	Patch closure	Recovery

Table 1 (continued)

Age	Sex	Author	Literature		Side	Onset (postope.)	Symptom	Therapy	Outcome
33	27 F	Tomita	Japanese	1977	R	48 h	Hypotension, cyanosis	Patch closure	Recovery
34	55 F	Arndt	Am J Roentgenol	1978	R	Immediately	Hypotension, tachycardia	Patch closure	Recovery
35		Rodgers	JTCVS	1979	L	1 h	Hypotension, varicosis	Direct suture	Recovery
36		Sekasegawa	Japanese	1979	R	Immediately	Unclear	Patch closure	Recovery
37	61M	Ebel	Chest	1980	R	2 h	Hypotension, varicosis	Patch closure	Recovery
38		Hidvegi	J Can Assoc Radiol	1981	L	8 h	Hypotension, varicosis	Pericardiotomy	Recovery
39	54 M	Uno	Japanese	1983	R	13 h	Hypotension, cyanosis	Patch closure	Recovery
40	59 M	Mitani	Japanese	1984	R	2 h	Hypotension, bleeding	Patch closure	Recovery
41	43 M	Cassoria	Anesthesiology	1984	R	7 h	Hypotension	Patch closure	Death
42	57 M	Takahashi	Japanese	1985	R	Immediately		Patch closure	Recovery
43	34 F	Castillo	Am J Roentgenol	1985	R	6 h	Shock	Patch closure	Recovery
44	59 M	Mitani	Japanese	1985	R	1.5 h	Hypotension, CVP elevation	Patch closure	Recovery
45	52 F	Weinlander	Anesth Analg	1986	R	Immediately	Hypotension	Direct suture	Recovery
46	52 M	Maeda	Japanese	1986	R	Immediately	Asymptomatic	Patch closure	Recovery
47	61 M	Ohta	Japanese	1991	R	1st day	Hypotension cyanosis	Patch closure	Recovery
48	58 M	Nakashima	Japanese	1992	R	23 h	Hypotension, cyanosis	Patch closure	Recovery
49		Forget	Ann Fr Anesth Reanim	1992	R	2 h	Hypotension, tachycardia	Patch closure	Recovery
50					R	2 h	Hypotension, tachycardia	Patch closure	Recovery
51	67 F	Kimino	Japanese	1993	L	48 h	Hypotension, cyanosis	Patch closure	Recovery
52	63 M	Sugamoto	Japanese	1994	R	5 h	Hypotension	Patch closure	Recovery
53	65 M	Nishiuchi	Japanese	1996	L	1.5 h	Hypotension cyanosis	Patch closure	Recovery
54		Vanoverbeke	Acta Chir Belg	1998	R	Immediately	Hypotension	Patch closure	Recovery
55	36 M	Self	Anesthesia	1999	R	Immediately	Asymptomatic	Patch closure	Recovery
56	64 M	Kimura	Japanese	1999	R	15 h	Hypotension, arrest	Patch closure	Recovery
57	58 M	Monterro	Chest	2000	R	Recovery room	Af	Direct suture	Recovery
58	49 M	Veronesi	EJCTS	2001	R	ICU	Bradycardia, hypotension	Repair the fat flap	Recovery
59	55 M				R	12 h	Hypotension	Patch closure	Recovery
60		Buniva	Tex Heart Inst J	2001	R	2 h	Asymptomatic	Patch closure	Recovery
61	67 M	Baisi	JTCVS	2002	L	7 h	Arrhythmia	Patch closure	Recovery
62	52 M	Shimizu	ATCVS	2003	R	Immediately	Hypotension, arrest	Patch closure	Recovery
63	59 M	Kjev	Am Surg	2007	R	Day 1	Ischemic change in ECG	Mesh closure	Recovery
64	33 M	Friso	Ann Thorac Surg	2004	R	6 months	SVC synd	Patch closure	Recovery
65	54 M	Chambers	Anaesth Intensive Care	2005	L	Recovery room	Lost consciousness	Patch closure	Recovery
66	70 F	Mahanna	J Thorac Imaging	2007	R	4 h	Hemodynamic instability	Patch closure	Recovery
67	44 M	Sonoda	J Anesth	2010	R	Immediately	Hypotension	Patch closure	Recovery
68	35 M	Gadhinglajkar	Ann Card Anaesth	2010	L	In motion to ICU	Vf	Patch closure	Recovery

Table 1 (continued)

Age	Sex	Author	Literature		Side	Onset (postope.)	Symptom	Therapy	Outcome
69	34 F	Steinmann	Case Rep Med	2010	R	Few hours	Hypotension	Drainage (Lt. pneumothorax)	Recovery
70	55 M	Kawamukai	Interact Cardiovasc Thorac Surg	2011	R	1 h	Asymptomatic	Patch closure	Recovery
71	69 M	Terauchi	Cardiovasc Interv Ther	2012	R	24 h	AMI	Patch closure	Recovery
72	69 M	Ponten	GTCVS	2012	R	24 h	Hypotension, CVP elevate	Patch closure	Recovery
73	68 M				L	48 h	Hypotension	Patch closure	Recovery
74	61 M	Fenstad	Circulation	2014	L	Immediately	Hypotension, bradycardia	Mesh closure	Recovery
75	46 M	Sanchis	Rev Esp Cardiol	2015	R	No data	Hypotension	Drainage (cardiac effusion)	Recovery
76	44 M	Zhao	J Cardiothorac Vasc Anesth	2017	L	35 min	Arrest	Patch closure	Recovery

M male, *F* female, *R* right, *L* left

reposition, and extubation [3]. Cardiac herniation occurs without any apparent cause; however, prevention of the conditions set forth above is a measure to avoid this complication. In the present case, cardiac herniation occurred as soon as the patient was switched to the spine position, and the chest tube was suctioned. Inappropriate timing and inappropriate pressure of the tube suction could have been the cause of the cardiac herniation in this case. Reposition and drainage should not be performed at the same time because these procedures may cause midline shift and fluctuations in intrathoracic pressure. Moreover, drainage should be started at a slow pace with sufficient monitoring. A postural shift (unaffected side down) and rethoracotomy of the patients yield recovery. The patient should be switched to the unaffected side down as soon as sudden hypotension is observed in such a situation.

We reviewed 76 cases that were reported in English (62 cases) or Japanese (14 cases) (Table 1) [4–6]. Of those, 54 (71.1%) were cardiac herniation after right pneumonectomy, and 22 (28.9%) were after left pneumonectomy. Moreover, 71 (93.4%) developed cardiac herniation within 24 h, 3 at 48 h, and 1 at 6 months after surgery [7]. Fourteen patients died from cardiac shock by herniation, or heart failure and infection secondary to herniation between 1948 and 1984. The most common symptom was hypotension with or without cyanosis, CVP elevation, varicosis or SVC syndrome. X-ray findings were also important as 5 (6.6%) patients were asymptomatic when diagnosed. A postural shift (unaffected side down) and rethoracotomy of the patients yield recovery.

Standard treatment is rethoracotomy. Initially, pericardiotomy was the main procedure for releasing herniation [4, 5]. However, the prognosis was poor and recurrence of herniation [8] was reported in such cases. Since the 1970's, almost all patients underwent patch closure in rethoracotomy to repair the cardiac herniation site [6]. Recently, some authors reporting cardiac herniation, stated that pericardial defects should be closed with a patch anchoring the pericardial edge rather than other weaker tissues [9] regardless of the size of the defect [10]. A PTFE membrane is loosely anchored to the residual pericardium by continuous sutures in our institute; in this case, however, cardiac herniation was induced by tear of the pericardium. Large defects and wide dissection of hilar tissue will be associated with an increase in pressure on the pericardial patch and sutured tissue. Technique of closure is required especially for patients with weakened tissues such as those advanced in age and patients who have just undergone radiotherapy or chemotherapy.

Early recognition, immediately after rethoracotomy increases the chance for survival. Especially, in right-sided herniation, torsion of the atriocaval junctions and great vessels results in reduction of blood return, leading to a dramatic fall in cardiac output [11]. If not treated quickly, this can result in myocardial infarction, hypotension, and ventricular fibrillation [12]. Even we were able to diagnose it immediately in this case, where the patient presented postoperative instability of cardiovascular status immediately after surgery. Urgent thoracotomy before irreversible myocardial damage is mandatory for managing cardiac herniation.

Conclusion

We report a case of cardiac herniation after right pneumonectomy. Early diagnosis and prompt reduction is necessary to avoid an unstable cardiovascular statement from cardiac herniation and damage caused by obstruction of blood flow.

We must prevent cardiac herniation by appropriate patch closure for anchoring the edge of the pericardium and we need to recognize the clinical characteristics of cardiac herniation for early intervention.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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