(AML) (fig. 1d). The patient was referred to oncology where he was treated for the blast crisis of AML. A repeat BAL fluid analysis after 14 days of treatment for PCP was negative for *P. jirovecii*.

HIV-positive patients with a CD4 count $<200\ \mu L^{-1}$ are considered at risk for PCP [1]. HIV-negative patients with PCP are predominantly those on immunosuppression or chemotherapy for an underlying disease process [2]. Irrespective of the underlying cause, the predisposition to PCP in the ''at risk'' patients is primarily due to a decrease in their cell-mediated immunity [3]. Additionally, in patients on glucocorticoids for >12 weeks, suppression of lung surfactant may be an additional factor [4]. Though haematological malignancies constitute 30% of all the malignancies associated with PCP, the median time from cancer diagnosis to the first episode of PCP is usually 2 yrs [2]. Moreover, PCP as the sole presenting feature of an underlying occult haematological malignancy has not been reported previously.

On presentation, our patient had no evidence of leukaemia. In retrospect, PCP was thus the first clinical manifestation of his occult malignancy. Though the blast crisis manifested 3 weeks after the first signs and symptoms of PCP, a bone marrow analysis would have revealed AML even on presentation. This would in turn explain the decreased immunity and, therefore, his predisposition to PCP. The infiltrates on CT scan of the chest could not be attributed to leukaemia because the WBC count was normal at that time. Serum LDH generally ranges from 361 $IU{\cdot}L^{-1}$ to 1,217 $IU{\cdot}L^{-1}$ in patients with PCP [5]. The higher than expected LDH served as an additional clue towards an underlying haematological malignancy in our patient.

In conclusion, PCP can thus be the sole atypical presentation of leukaemia. Since the transformation time from occult to overt leukaemia can be variable (weeks to months), bone marrow analysis should be considered in HIV-negative patients with no identifiable risk factors for PCP on presentation.

G. Sandhu*, R. Dasgupta#, A. Ranade¶ and M. Baskin#
*Dept of Internal Medicine, #Division of Pulmonary and Critical Care, and ¶Dept of Pathology, St. Luke's – Roosevelt Hospital Center, Columbia University College of Physicians and Surgeons, New York, NY, USA.

Correspondence: G. Sandhu, 1111 Amsterdam Avenue Clark 6, New York, NY 10025, USA. E-mail: gsandhu@chpnet.org

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Unusual treatment of patent foramen ovale after pneumonectomy

To the Editors:

As has often been said by Dr Harold C. Urschel Jr, pneumonectomy is ''a disease'' in itself. It is a major procedure with frequent perioperative complications such as empyema, fistula, cardiac problems or respiratory insufficiency. Besides frequent post-operative cardiac and respiratory complications, long-term sequelae are also seen.

After pneumonectomy, anatomical adaptations occur with repositioning of intrathoracic structures. Common changes are elevation of the hemidiaphragm (especially after phrenic nerve damage), mediastinal shift, diminished intercostal space and filling of the postpneumonectomy space with fluid. Infrequently, these adaptations may lead to invalidating complications. The most frequent complication is the so-called post-pneumonectomy syndrome caused by compression of the remaining bronchus against the vertebral column or aorta. Since positioning of the organs may take years, symptoms may occur even after 5–10 yrs.

In this letter, we will focus on a rare complication, shunting through a patent foramen ovale (PFO), as a long-term complication of right-sided pneumonectomy or bilobectomy. Only a few cases have been published, although this complication might be under-reported since the diagnosis of PFO is difficult, especially after pneumonectomy. This letter describes three patients who were diagnosed with shunting through a PFO following lung resection. In these patients, right ventricular compression by the elevated right hemidiaphragm was the main cause of PFO and surgical plication of the right hemidiaphragm was sufficient to close the PFO.

CASE SERIES

Patient A

A 67-yr-old male underwent a right-sided pneumonectomy 14 yrs earlier because of a bronchial carcinoid. Partial resection of the pericardium with transection of the phrenic nerve were needed for complete resection He developed progressive

dyspnoea during exercise and when bending down. Echocardiography demonstrated a right-to-left interatrial shunt when increasing intra-abdominal pressure (valsalva manoeuvre) with a shunt fraction of 18%. Further analysis with right heart catheterisation at our institution showed a mean right atrial resting pressure (P_{ra}) of 3 mmHg, a mean pulmonary artery pressure (P_{pa}) of 15 mmHg and a wedge of 5 mmHg (all normal). However, when increasing the intra-abdominal pressure by raising his legs, the mean P_{ra} increased to 26 mmHg, whereas right ventricular pressure (P_{rv}) and P_{pa} remained unchanged. Thus, by increasing the intra-abdominal pressure, a right-to-left interatrial shunt was created through a pressure gradient mechanism. Indeed, a dynamic magnetic resonance image (MRI) (with raised abdominal pressure by elevating of both legs) showed compression of the right ventricle by his elevated diaphragm and also a shunt through his PFO.

For this reason, a rethoracotomy was performed for surgical plication of the diaphragm. Post-operatively, his complaints disappeared completely and no desaturation was observed during bending.

Patient B

This 65-yr-old female received a right-sided pneumonectomy for non-small cell lung carcinoma of the bronchus. 10 months later, she presented with dyspnoea on excertion. Cardiopulmonary exercise testing (cycling) demonstrated an impressive desaturation from 93% to 85% at her maximum exercise level of 30 Watt. Furthermore, echocardiography showed a small right atrium and ventricle with a right-to-left interatrial shunt. At right heart catheterisation, we measured a resting mean P_{ra} of 5 mmHg, a mean P_{pa} of 15 mmHg and a wedge of 5 mmHg. Dynamic MRI showed a complete right ventricle compression by her elevated diaphragm. Thus, also in this patient right-to-left shunting through a PFO and compression of the right ventricle by the diaphragm coincided. Therefore, a causal relation was again likely. We performed surgical correction of the diaphragm by plication. Post-operatively, we found no evidence of right-to-left shunting; her resting saturation was 98% and during cardiopulmonary exercise testing was 92%. 5 months later, she developed dyspnoea again. This time, we found a post-pneumonectomy syndrome by compression of the left main bronchus due to a mediastinal rotation. A third thoracotomy at the right side was performed for mediastinal repositioning and placement of two saline filled prostheses. Afterwards, the patient was able to perform her daily activities again.

Patient C

13 months after resection of the right lower lobe and right middle lobe for non-small cell lung cancer, a 65-yr-old female presented with progressive dyspnoea which could not be relieved by oxygen therapy. The dyspnoea was worst when laying on her right side or supine. During the pulmonary surgery, the phrenic nerve had been resected *en bloc* with the tumour resulting in a paralysis of the diaphragm. Echocardiography demonstrated flow through a PFO and normal function of the ventricles. The P_{pa} was normal (9 mmHg). Dynamic MRI showed a paralysed, elevated diaphragm pushing against the right ventricle, causing compression and rotation of the heart (fig. 1). Especially during inspiration, an almost complete compression of the right ventricle occurred with an interatrial right-to-left shunt. This phenomenon could be explained by the paradoxical upward movement of the paralysed diaphragm during inspiration, compressing the right ventricle. Because of outflow impairment of the right ventricle, the increased pressure caused a flow through a PFO. The same mechanism occurred when intra-abdominal pressure was increased. When sitting, the saturation was 91% and in the supine position it decreased to 85%.

Thus, once more, we observed compression of the right ventricle by the elevated diaphragm. Due to her condition the patient was deemed unsuitable for open cardiac surgery. Percutaneous closure of the PFO was also discarded as it would not correct the compression of the ventricle. So a right sided thoracotomy was performed with plication of the diaphragm. Post-operative recovery was complicated by a pneumonia which was treated successfully with antibiotics. Compression of the ventricle and intra-cardial shunting no longer occurred.

DISCUSSION

Dyspnoea after pneumonectomy or bilobectomy has a wide differential diagnosis. In our case series it was caused by diaphragmatic relaxation compressing the right ventricle with subsequent outflow obstruction leading to a significant right-left shunt through a PFO. Plication of the diaphragm resolved the interatrial pressure gradient and subsequently stopped the flow through the PFO.

Treatment of interatrial shunting is preferably done by percutaneous transcatheter closure [1–3]. In our patients, the shunt through the PFO was only one aspect of the right ventricle compression. After a percutaneous closure, the shunt may cease, but the right ventricle compression by the diaphragm has not been stopped and neither will the right atrial pressure go down. Therefore, we postulated it may be more logical to remove the cause of the shunting when the condition of the patient allows surgery. Finally, a percutaneous procedure was technically not possible in the third patient.

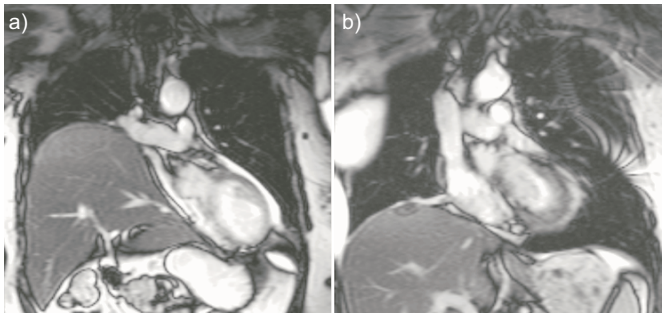

FIGURE 1. Coronal magnetic resonance image of patient C, a) before and b) after plication of the right hemidiaphragm. After plication, the pressure on right atrium and right ventricle is released, and thereby a functional repair of the patent foramen ovale and right-to-left shunt is accomplished. Settings on the Siemens 1.5T MRI system (Siemens Medical Solutions, Erlangen, Germany) were: electrocardiogram-triggered single-shot Steady State Free Precession imaging, trigger delay 440 ms, acquisition window 418 ms, slice thickness 5.5 mm.

In the patients described, the flow through the PFO was not continuous, but intermittent. When increasing intra-abdominal pressure, a right-to-left interatrial shunt was created through a pressure gradient mechanism. In the first patient, this intermittent flow was dynamically shown by means of a Valsalva manoeuvre during echocardiography. In addition, when raising the legs during right heart catheterisation, the P_{ra} increased as a sign of right atrial outflow obstruction. Finally, a dynamic MRI showed compression of the right ventricle when increasing intra-abdominal pressure. Intermittent shunting also explains the position-dependent dyspnoea in our patients; especially when bending down, when lying on the right side or supine, the elevated diaphragm compresses the right ventricle starting the flow through the PFO.

According to literature, a PFO occurs frequently. In an autopsy study, the incidence was 27.3% [4]. Shunting through a PFO seems to be less common. This might be due to the fact that the shunt is intermittent and since resting haemodynamics are usually normal the shunt can easily be missed. However, SUN *et al.* [5] showed, among patients with pulmonary hypertension, a prevalence of 45% of shunting through a PFO. Therefore, this might also be the case in patients with right ventricle compression. Furthermore, our patients were seen in a referral hospital and may therefore be a selected group.

SCHNABEL *et al.* [6] in 1956, and others [7], reported reported on the first patient with a right-to-left shunt without elevated right sided heart pressures after a right sided pneumonectomy. Right sided pneumonectomy will lead to a repositioning of intra-thoracic structures, which might lead to several complications, due to compression of cardiac structures. Since the repositioning of the organs may take years, symptoms might occur several years after the pneumonectomy. According to MARINI *et al.* [2] and BAKRIS *et al*. [8], atrial stretching may be the mechanism of blood flow through a PFO in the absence of a pressure gradient. This would particularly occur in the presence of mediastinal distortion, when the right atrium is shifted away, while the inferior vena cava remains fixed in position. AIGNER *et al*. [9] described haemodynamic complications due to a shunt through a PFO caused by a combination of changed anatomic position of the left atrium and elevated pulmonary artery pressure leading to a significant right-to-left shunt. However, our patients had a normal pulmonary artery pressure. In addition, pulmonary hypertension is very rare among post-pneumonectomy patients. Therefore, pulmonary hypertension was not the cause of the dyspnoea in our post-pneumonectomy patients.

Dyspnoea as a long-term complication after pneumonectomy due to a right-to-left shunt induced by right cardiac compression is rare. It can occur at variable time points after pneumonectomy. Due to a low awareness of this potential complication, the diagnosis is difficult and often established late. In our series, right-to-left shunting through a PFO occurred because of an outflow obstruction of the right ventricle due to an elevated diaphragm (fig. 2). No pulmonary hypertension existed. Dyspnoea was relieved by surgical plication of the elevated diaphragm.

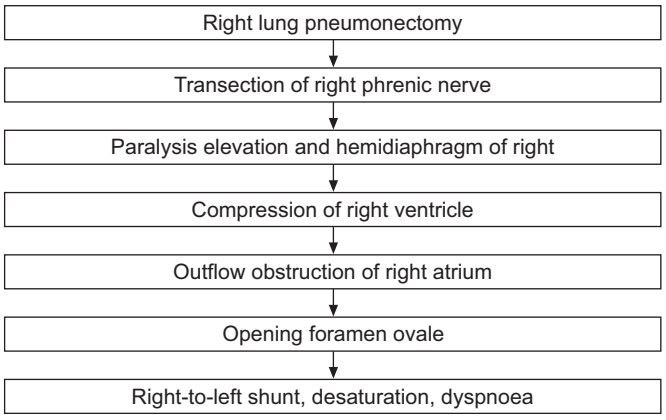

FIGURE 2. The mechanism of dyspnoea after pneumonectomy, as observed in the present study.

W.N. Welvaart*, A. Becker#, J.T. Marcus#, A. Vonk-Noordegraaf#, J.W.A. Oosterhuis* and M.A. Paul*

Depts of *Surgery and #Pulmonology, VU Medical Center, Amsterdam, The Netherlands.

Correspondence: W.N. Welvaart, Rivierenland Hospital, Surgery, President Kennedylaan 1, Tiel, 4002 WP, The Netherlands. E-mail: w.welvaart@zrt.nl

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