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Case report

Anatomical changes after pneumonectomy

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SUMMARY

Pneumonectomy is associated with many diverse post-operative conditions, e.g. hydropneumothorax, diaphragm elevation, progressive mediastinal displacement, thorax wall deformation, and hydrothorax. By means of imaging procedures, such pneumonectomy-related anatomical changes can easily be determined; here we summarize some of the common diagnostic findings and in addition report the case of a 100-year-old woman, who underwent left pneumonectomy at the age of 47, survived for another 53 years with only one lung and then became body donor to our department. Investigation of the cadaver revealed that, compared to similar-aged individuals still having both lungs, mediastinal structures had been displaced to the side of the missing lung. In addition, the remaining lung had herniated across the midline to a position anterior to the heart. Histological examination of the remaining lung tissue revealed changes comparable to those generally expected in lungs of individuals of the same age-group; tissue changes directly associated with pneumonectomy could not be observed. The findings document anatomical alterations that arise physiologically due to pneumectomy if no pathological complications occur.

1. Introduction

Pneumonectomy, the surgical removal of an entire lung, is the treatment of choice for bronchogenic carcinoma (Chae et al., 2006) and malignant lung diseases (James and Faber, 1999). For example, a pneumonectomy is often indicated in cases of large tumors with interlobular growth or with extensive involvement of the main bronchus (Dienemann, 2005). In addition, pneumonectomy may occasionally be required in the treatment of various non-malignant diseases, such as inflammatory lung disease, as well as in the treatment of intractable end-stage lung diseases (e.g. pulmonary tuberculosis, fungal infections, bronchiectasis, chronic obstructive pulmonary disease), traumatic lung injury, congenital lung disease, and bronchial obstruction in a damaged lung (Conlan and Kopec, 1999; Chae et al., 2006). Many complications and a variety of reasonably predictable anatomical and physiologic changes occur in patients who have undergone pneumonectomy (for review, see Kopec et al., 1998). For example, significant decrements in pulmonary function and a number of potential complications that involve the respiratory system, the cardiovascular system, and the pleural space are associated with pneumonectomy (Kopec et al., 1998). Post-operative difficulties include cardiac arrhythmia, myocardial infarction, or other heart problems, pneumonia, infection of the incision site, pulmonary embolism, broncho-pleural fistulae, empyema, and failure of the kidney or other organs (Kopec et al., 1998; Reed, 1999). Further consequences of pneumonectomy are anatomical and physiological changes of the esophagus (Suen et al., 1999, 2002) and different degrees of fluid accumulation in the post-pneumonectomy space (Kopec et al., 1998).

Following pneumonectomy, approximately 30% of patients suffer atrial and ventricular arrhythmias (Dienemann, 2005). In up to 10% of patients broncho-pleural fistulae appear (disrupted healing of the main bronchus), whereby an insufficiency of the main bronchus after pneumonectomy accounts for up to 50% of mortalities (Dienemann, 2005). According to Dienemann (2005), delayed post-operative complications occur to different extents and are obvious more often following pneumonectomy than following lobectomy; these include thorax deformation, displacement of mediastinal organs, and hemodynamic modifications such as cor pulmonale (pulmonary hypertension). A rare complication secondary to post-surgical anatomical changes in the pneumatic space is the development of post-pneumonectomy syndrome (Kalluri et al., 2008).

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In the present study representative clinical findings and complications following pneumonectomy in different patients were considered using diagnostic radiology with computer tomography (CT), magnetic resonance imaging (MRI) scans and chest radiography. In addition, we report here on an especially interesting case of a female, whose body was donated to our department for an undergraduate dissection course; preparation was carried out with standard embalming techniques. After opening the body, we noted that the left lung was missing. Because of the unusual age of the woman at death (100 years) and her long lifespan with only one lung, we here describe all anatomical changes found in the thorax and additionally performed histology of the tissue of the remaining lung.

2. Case report

Clinical patients who have undergone pneumonectomy show numerous post-surgical alterations in chest radiography, CT and MRI examinations. Fig. 1 illustrates some of the typical consequences of pneumonectomy using these different imaging techniques. A typical post-operative case history following pneumonectomy is characterized, first, by the development of a radiologically visible accumulation of fluids in the empty lung cavity with a sickle of air above it (hydropneumothorax, Fig. 1A—patient after 7 months); the air is reabsorbed within days to weeks. In some patients in addition to elevated diaphragm (Fig. 2B—a hydrothorax) (Fig. 1C, E and F; accumulation of serous fluid in the thorax) is, however, still detectable after a period of 3 up to 18 years, but can also recede in some cases (patient 16 years post-operative). Furthermore, post-operatively, elevation of the diaphragm on the side of the removed lung (Fig. 1A–D), thorax deformation (Fig. 1D–F) and progressive displacement of the mediastinum can occur (Fig. 1G–I). These post-operative consequences of pneumonectomy can also be detected after longer periods of time (e.g. after 18 years).

Moreover, we document here the first known case of a woman whose lung was removed at the age of 47 and who survived another 53 years with the remaining right lung. The medical history of this woman was reconstructed from medical records provided by the general practitioner and by further information supplied by a son. The patient bore two healthy children when she was 28 and 35 years of age. During World War II she lived through the attacks on Leuna's chemical plants and subsequently suffered the effects of the poisonous gases that developed during the assaults. These experiences led to chronic dyspnea and shortness of breath. The treatments provided during several stays at rehabilitation facilities were initially focused on asthma. During several of these stays pleura biopsies were carried out. As a result, total atelectasis was diagnosed, precipitated by bronchial adenoma of the main bronchus in the left lung. As a consequence, at the age of 47, the woman underwent a left pneumonectomy. Some of the documented post-operative complications of the pneumonectomy were liver pain, spinal curvature, and circulatory problems.

In the framework of our dissection course for medical students, the thorax from the embalmed body of this woman was prepared. During preparation procedures the missing left lung was noted. As a result we compared the anatomical anomalies in the thorax of the cadaver with those of other cadavers of the same age. The upper lobe of the right lung had herniated across the midline anterior to a position in front of the heart (Fig. 2A). The lung itself was not strongly discolored through fine dust particles or tobacco smoke, when compared to the lungs of other cadavers, rather, for the most part, it showed white–gray discoloration. In general, the lung presented an overall healthy appearance. As a result of removal of the left lung, there was dramatic rotation and shifting of mediastinal structures, like the heart including its afferent and efferent vasculatures (Fig. 2B and C). The opening of the pericardium evidenced massive bleeding into the pericardial cavity. As a result, the heart was strongly compressed which very probably led to the death of the body donor. Acute cardiac insufficiency was given as the cause of death. The women suffered, according to her medical records, from diabetes mellitus as well as angiosclerosis.

Tissue samples were taken from both the upper and lower lobes of the remaining right lung of this 100-year-old woman. Furthermore, a tissue biopsy of the liver was taken. Similarly, cadavers of approximately the same age (99-years-old, male, and 91-years-old, female) tissue samples were taken from both the right lung and liver of each. Macroscopically, all tissues were in good condition. From each of the collected samples, 5 μm thin sections were prepared and stained with hematoxylin and eosin.

During examination of the lung tissue of the 100-year-old women an age-related middle alveolar emphysema as well as indication of a bronchiolitis (inflammatory swelling of the mucus membranes of the bronchiole) were determined. In addition inclusions of soot were detected. Medical evidence indicated that, overall, the alveolar septa and bronchiolar architecture can be considered normal taking age into consideration and the vascular texture can be described as regular (Fig. 3A and B). The lung did not show any alterations due to pneumonectomy. In the area of the main bronchus, ossification in the scar tissue was detected, surrounded by adipose tissue and collagen-rich connective tissue. In comparison the lung tissues of the other two cadavers (female 91 years, male 99 years) were in poorer condition (Fig. 3C and D). In the 99-year-old cadaver the alveoli were acutely overinflated (distinct adult-onset emphysema). Further findings were: anthracosis, scaling of cells, a marginally distinct peribronchitis, and a discrete alveolar cell catarrh. In addition, pus, mucus spirals and mucus plugs were found conspicuously often in the lumen of the bronchiole (not shown). The lung tissue of the 91-year-old body donor showed slight septation, as well as chronic inflammation of the interstitium and an accumulation of iron and soot particles (not shown).

Examination of the liver tissue of the 100-year-old cadaver who had undergone pneunomectomy revealed congestion of the central vein, and the hepatocytes exhibited large nuclei. Between hepatocytes (characterized by highly active nuclei) interdispersed adipose cells and accumulations of granulocytes were found (not shown). Comparative histological features were detected in the liver tissue of the 99-year-old cadaver (not shown). The liver tissue of the 91-year-old body donor was distinguished by wide sinusoids containing large amounts of blood and fibrin (not shown).

3. Discussion

Typical delayed post-operative effects due to pneumonectomy can present themselves in the musculoskeletal system, e.g. thorax deformities in terms of altered spacing of the ribs (Steveling et al., 2007). Through imaging techniques, such deformities of the thorax wall can also be seen in our patient group long after pneumonectomy. Furthermore, in correspondence with the post-operative changes documented here, elevation of the diaphragm and the displacement of mediastinal structures (heart, esophagus, vagal nerves), which may be factors triggering arrhythmia, have been described (Steveling et al., 2007). Cardiac arrhythmias are well documented in the early post-peumonectomy period (Foroulis et al., 2003).

Displacement of the heart, along with its blood vessels and nerves, towards the left breast cavity could be determined in the 100-year-old body donor after preparation of the thorax. The heart was shifted completely into the left pleural cavity, and the aortic arch was also relocated to a position further left (Fig. 2). The superior lobe of the residual lung was herniated across the midline.