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Diagnostic yield of computed tomography and densitometric measurements of the lung in thoracoscopically-defined idiopathic spontaneous pneumothorax

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In the present study, the diagnostic yield of high resolution computed tomography (HRCT) is evaluated in patients with thoracoscopically-verified idiopathic spontaneous pneumothorax (SP). Visual assessment as well as densitometry of lung parenchyma was performed. In eight of the 20 prospectively-evaluated SP patients, emphysema-like (EL) changes such as blebs and bullae could be detected. The SP patients with EL changes were significantly older and were more heavy smokers. Spirometrically-controlled CT lung densitometry showed no differences between the patient group with or without these EL changes. Comparing the densitometric measurements of the patient group with a healthy control group no significant differences in densitometry between both groups were found.

In conclusion, this study confirms that HRCT is a reliable method of detecting blebs and bullae in patients with spontaneous pneumothorax. Furthermore CT lung densitometry revealed no parenchymal abnormalities or signs of air trapping in patients with spontaneous pneumothorax.

Key words: spontaneous pneunothorax; computed tomography; densitometry; thoracoscopy.

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Introduction

Spontaneous pneumothorax is a frequently occurring problem in pulmonary practice. It is generally subdivided into primary or idiopathic pneumothorax, which occurs in healthy individuals without any known aetiology or secondary or symptomatic pneumothorax, which is associated with a variety of underlying lung diseases. In the diagnostic work-up of spontaneous pneumothorax, thoracoscopy is a commonly applied diagnositic procedure to visualize the pleural surfaces as well as the lung itself (1), in order to subdivide spontaneous pneumothorax and to direct therapeutic interventions. However, data confirming thoracoscopically-based classification of idiopathic spontaneous pneumothorax by modern imaging procedures such as high resolution computed tomography (HRCT) are scarce. Furthermore, the cause of spontaneous pneumothorax is still a matter of debate (2). Although a relationship between the rupture of subpleural blebs or bullae into the pleural space is generally considered, studies on the possible role of more general parenchymal involvement are lacking. Boutin and Astoul (1) recently stated that in spontaneous pneumothorax, minute emphysematous bullous lesions and blebs are seen in nearly all patients when examined with high resolution equipment and that it is reasonable to assume that there can be no 'normal lung' in spontaneous pneumothorax.

Also, smokers have also been found to have a higher incidence of spontaneous pneumothorax than non-smokers (3). CT and especially HRCT are at present generally accepted as sensitive imaging procedures to assess the presence and extent of lung parenchymal abnormalities (4–6).

Furthermore, densitometry of the lungs by CT has been developed as an useful, non-invasive and observer-independent method to determine the extent of lung parenchymal abnormalities (7). By performing CT scanning at an inspiratory and expiratory level, air trapping in small airways as a marker of peripheral airway obstruction as

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well as emphysematous destruction of lung parenchyma can be detected even in asymptomatic cigarette smokers (8,9).

The aims of the present study were therefore: firstly, to validate prospectively the findings of thoracoscopy with visual assessment of thin section CT of the lungs in patients staged thoracoscopically as idiopathic spontaneous pneumothorax (ISP) and, secondly, to assess possible early parenchymal as well as peripheral airway abnormalities in these patients with spontaneous pneumothorax by lung densitometry.

Material and methods

Twenty patients (14 males, six females) with spontaneous pneumothorax in the absence of a history of pre-existing pulmonary problems participated in this study. Mean age of the study group was $32{\cdot}3 \pm 9{\cdot}7$ years (range 20–52 years); 16 patients were current smokers ($11{\cdot}4 \pm 8$ pack-years).

After admission, thoracoscopy was performed in the lateral decubitus position, under local anaesthesia with lidocaine 2%. A 10-mm diameter trocar (Störtz, Tuttlinger, Germany) was inserted in the fourth or fifth intercostal space at the mid-axillary line. Thoracoscopy was supervised or performed by an experienced senior chest physician. Patients were included in the study when endoscopic inspection of the pleural surface of the lung was described as normal; i.e. absence of blebs of bullae after careful endoscopic inspection. All included patients were thoracoscopically classified as idiopathic. At the end of the procedure pleurodesis was performed by insufflation of 2 g of sterile asbestos-free iodized talc into the thoracic cavity.

After the pleurodesis a thoracostomy tube (CH–20) was inserted into the pleural cavity and connected to underwater seal suction with a negative pressure of 15 cm H_2O for at least 3 days. HRCT scan of the thorax and pulmonary function tests were performed at least 8 weeks (mean 13·3 weeks; range 8–20 weeks) after discharge of the patients from hospital.

Spirometric measurements were performed by wet spirometry. Inspiratory vital capacity (IVC) and forced expiratory volume in 1 sec (FEV_1) were expressed as a percentage of the reference values (10). The diffusing capacity corrected for the alveolar volume (KCO) was measured by the single breath method (Masterlab® Jaeger, Würtzburg, Germany); measured values were expressed as a percentage of the reference values (10).

All HRCT scans were performed with a Somaton Plus Scanner (Siemens, Erlangen, Germany).

HRCT scans of the thorax were obtained at end-inspiration with the patients in a supine position. The examination consisted of a series of 1-mm thin sections at 10-mm intervals from the apex of the lungs to the diaphragms. Scans were reconstructed in high resolution mode. Images were photographed at window levels appropriate for visualization of the pulmonary parenchyma (-800 H; window width 1600 HU). Localization and size of blebs (i.e. <2 cm diameter) or bullae (i.e. ≥ 2 cm diameter) were scored; furthermore presence of blebs or bullae on the ipsilateral (side of penumothorax) and/or contralateral side was registered as well as parenchymal abnormalities evident for emphysema pulmonum and pleural abnormalities.

In addition 1-mm collimation CT scans for quantitative assessment of lung density were obtained in the supine position. Scans were reconstructed in standard resolution mode. No contrast medium was injected. In order to control the respiratory status the patient was asked to breath through a hand-held spirometer, (Micro Medical Instruments, Rochester, U.K.), which was connected to the CT scanner. The respiratory status was constant for the duration the CT scan was made (11). Two anatomical levels were chosen using the scout view: 5 cm above and 5 cm below the level of the carina. At each level two scans at 90% and 10% of the vital capacity (VC) respectively were performed. The parenchyma of both lungs was delineated automatically by a density-discriminating computer programme (12). The mean lung density expressed in Hounsfield units (HU) was calculated for the purpose of this study. Results of densitometric analysis were compared with those of a group of 20 healthy males (mean age 53 ± 12 years; pack-years 17 ± 12) with no history of pulmonary diseases and normal lung function testing (FEV_1 $110 \pm 18\%$ predicted, KCO $90 \pm 9\%$ predicted). Volunteers were recruited by advertisement. Statistical analysis was performed using a Student's *t*-test. A two-tailed probability value of less than 0·05 was considered as statistically significant.

The study was approved by the local Medical Ethics Committee and written informed consent was given by all participating patients and healthy volunteers. In the control group only the densitometric measurements were performed because of the radiation hazard; HRCT (consisting of one topogram and 20–24 tomograms) had an effective radiation dose of 1·0–1·2 in mSU while a complete densitometric investigation (consisting of one topogram and four tomograms) caused an effective dose of 0·20 mSU.

Results

In 12 of the 20 patients thoracoscopically staged as having an idiopathic pneumothorax no blebs or bullae were found in the affected or in the contralateral lung (age 29 ± 9 years; pack-years 9 ± 6). In eight patients blebs or bullae (bullae: six patients, blebs: two patients) were detected in the affected lungs on HRCT scan (age 38 ± 9 years; pack-years 18 ± 7). These lesions were located in the apical subpleural regions as well as at the mediastinal side in four patients (Fig. 1). Remarkably, all patients with blebs or bullae in the affected lung also blebs or bullae in the contralateral lung on HRCT scan. No major pleural changes could be observed by HRCT. Two patients in the SP group had marked emphysematous changes on HRCT scan. Both patients had manifested panacinar emphysema in upper and lower lung fields. As expected, densitometric measurements were markedly decreased in these patients: upper lung densitometry was -896 and -878 HU at 90% vital capacity, lower lung densitometry was -845 and -880 HU at 90% vital capacity. One patient had a slightly decreased

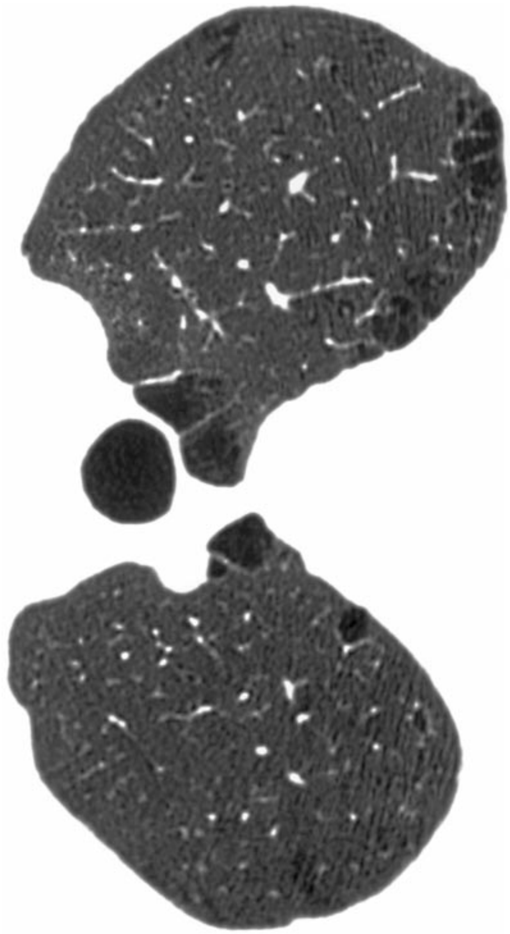

FIG. 1. HRCT scan through the upper lung zones of the lung showing subpleural blebs.

diffusion capacity (63% predicted). Both patients were current smokers: 25 and 15 pack-years respectively.

The patient group with and without blebs or bullae differed significantly in age (38 *vs.* 29 years; $P<0{\cdot}05$) and pack-years (18 *vs.* 9 years; $P<0{\cdot}05$). No differences were found in lung function parameters between both groups. Spirometrically controlled densitometric measurements could be performed in 18 patients. In both lung zones and at both levels of inspiration the mean lung density (MLD) of patients with ISP did not differ significantly from the MLD of the control group (Table 1).

Furthermore, no differences in densitometric data were seen between the patient group with and without bullous lesions. At 10% and 90% VC the mean lung density of the affected lung did not differ significantly form the contralateral side (Table 1). The change in mean lung density between 10% and 90% VC was 87 ± 43 HU in the affected lung and 97 ± 55 HU, in the healthy lung ($P=0{\cdot}55$, NS).

Discussion

Our findings demonstrated that HRCT scan has to be considered as a more sensitive method to detect blebs and bullae even in those patients thoracoscopically staged as idiopathic, and that thoracoscopical staging does not exclude existence of localized parenchymal abnormalities. However densitometric measurements of lung parenchyma in patients with idiopathic spontaneous pneumothorax exclude a more generalized parenchymal involvement. The present study confirms previous data obtained after thoracotomy. Evaluation of thoracoscopic findings with results of thoracotomy concerning the existence of blebs and bullae indeed demonstrated that thoracotomy frequently revealed presence of blebs and bullae in SP patients thoracoscopically staged as idiopathic (13).

In our selected patient population, thoracoscopically staged as idiopathic, blebs or bullae could be detected in 40% of the patients, especially in the older patients with more pack-years. In general, a lower sensitivity of thoracoscopy could possibly be explained by many procedure-related factors such as the level of experience of the operator, the level of atelectasis of the lung during the procedure as well as the possible degree of inspection of the lung surface. In our study approach we have tried to overcome these factors as carefully as possible as described in the methods. Our study indicate a high percentage blebs or bullae in the subpleural regions as well as at the mediastinal site.

As well as visual assessment of the lung parenchyma, HRCT allows density calculations of the different structures of the lung to be performed. These densitometric calculations can be performed on different predetermined lung volumes.

Spirometrically-controlled HRCT measurements also permit calculation of density differences between inspiration and expiration as an imaging tool, reflecting the degree of trapped air during expiration (7). In the present study no differences in parenchymal density could be demonstrated between patients with spontaneous pneumothorax and a normal control population. Furthermore, no differences were demonstrable between the affected lungs or contralateral lungs, between lungs with so-called emphysema-like changes such as blebs or bullae, and lungs without these visible changes. The absence of significant differences between lung densitometric values in patients with emphysema-like changes and patients without these changes further confirms the absence of generalized parenchymal pathology in spontaneous pneumothorax. Furthermore, no differences in density between the inspiratory–expiratory ratios were found between pneumothorax patients and control subjects, indicating an absence of marked air trapping in patients suffering from pneumothorax. Densitometric assessment as performed in the present study can be considered as a reliable and observer-independent procedure in the evaluation of air trapping (7).

Air trapping has to be considered as a consequences of a check valve phenomenon in the peripheral airways due to bronchiolar inflammation (14).

Previous studies have suggested the presence of peripheral airway obstruction in the patients with spontaneous pneumothorax (15). At least in this selected group of patients with thoracoscopically staged idiopathic spon-

TABLE 1. Densitometric results at 10% and 90% vital capacity

Vital capacity (%)	Patient group ($n=18$) Mean ± SD	Control group ($n=20$) Mean ± SD	Patient group (affected lung) Mean ± SD	Patient group (contralateral lung) Mean ± SD	*P*
Upper zones					
90	−850 ± 32	−858 ± 29	−847 ± 32	−852 ± 22	NS
10	−758 ± 69	−757 ± 74	−758 ± 68	−786 ± 39	NS
Lower zones					
90	−838 ± 26	−847 ± 34	−836 ± 28	−841 ± 26	NS
10	−731 ± 60	−767 ± 56	−738 ± 54	−724 ± 68	NS

All values are expressed in Hounsfield units (HU). SD: standard deviation; ISP: idiopathic spontaneous pneumothorax; NS: not significant ($P > 0{\cdot}05$).

taneous pneumothorax no signs of air trapping were present.

Based on the rather low sensitivity of thoracoscopy to detect blebs and bullae, as demonstrated in the present study, the role of this invasive procedure in the diagnostic work-up of spontaneous primary pneumothorax can be questioned. Furthermore, Schramel *et al*. concluded in their study that the presence of blebs and/or bullae has no additive value in the prediction of future recurrences of primary pneumothorax (16). In the group with presence of emphysematous-like changes in the contralateral lung, no occurrence of pneumothorax on that site was observed after a follow-up period of at least 24 months in the present study. Therefore, our data also differ from recent observations reported by Sihoe *et al*. that detection of lung bullae by CT scanning in the contralateral lung following unilateral primary spontaneous pneumothorax is associated with a higher rate of subsequent occurrence of pneumothorax in that lung (17). We therefore believe that larger prospective studies have to be performed to delineate the role of CT scanning in the work-up of patients with primary spontaneous pneumothorax.

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