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Diagnosis of emphysema and air-trapping in high resolution computed tomography

Conventional computed tomography has several limitations, related to long scanning time and using 1 cm thick collimation. Improvement in the quality of images of lung parenchyma, led to the development of high-resolution computed tomography (HRCT). It optimizes the morphological images of the lung parenchyma at the level of the lung lobule, becoming the modality of choice in evaluating the lung interstitium (11). The most important modifications of the technique that decide about high resolution are thin collimation (2–3 mm) and reconstruction of the images with use of sharp (bone) algorithm (24).

The aim of the study was assessment of the usefulness of HRCT in diagnosis of emphysema, determining its character and presence of air-trapping.

MATERIAL AND METHOD

Material comprises a group of 45 patients, aged between 34 and 68 years. Scans were obtained with the patients supine, during suspend full inspiration with 1-cm scan spacing. The scans collimation was 2 mm. The scanning was performed from the lung apices to basis. The lung window width of 1600 H.U. and the window mean of –600 H.U. were used. In all patients additional expiratory scans were performed, and in the cases of opacities in dependent lung regions, prone scans were obtained. All patients also have plain radiographs of the chest, both inspiratory and expiratory. The nonparametric statistical McNemar's χ^2 test was performed to compare diagnostic accuracy of plain radiographs and HRCT in revealing emphysema and air-trapping.

RESULTS

In the 16 patients the pneumoconiosis was found, 9 patients had sarcoidosis and 8 tuberculosis, 6 has pneumonia, 4 patients were with bronchiolitis and 2 with histiocytosis X. In 8 patients the centrilobular emphysema was found, as a focal lucency in the middle of the lobule (Fig. 1).

In the pneumoconiosis the centrilobular and irregular, patchy emphysema was accompanied by disseminated nodular changes (Fig. 2). In all patients the vascular pattern was reduced (Fig. 3). In 6 patients the emphysema was panlobular, as patchy regions of decreased

lung density, with reduction of sizes and number of small pulmonary vessels (Fig. 4). The patch regions of emphysema were usually accompanied by others parenchymal changes (Fig. 5). In 11 patients thin-wall bullous emphysema was found, localized mainly in sub-pleural regions (Fig. 6). Subpleular emphysema usually involved linear regions. In 12 cases the regions of

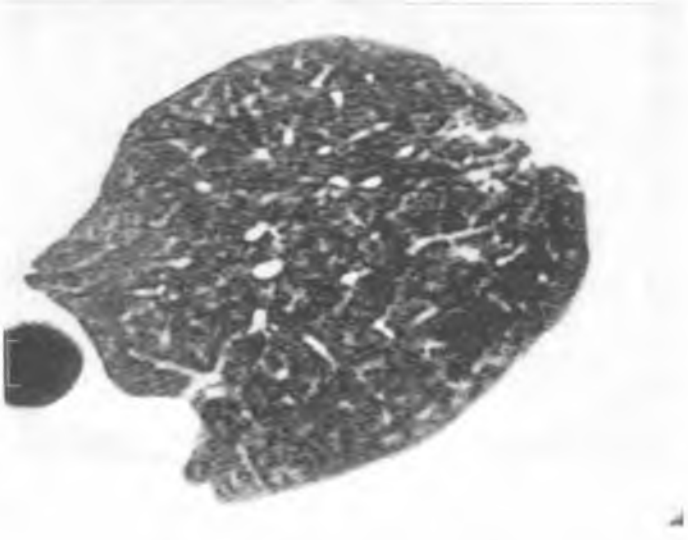

Fig. 1. The disseminated, fibrotic nodular changes, localized centrilobular, surrounded with border of centrilobular emphysema

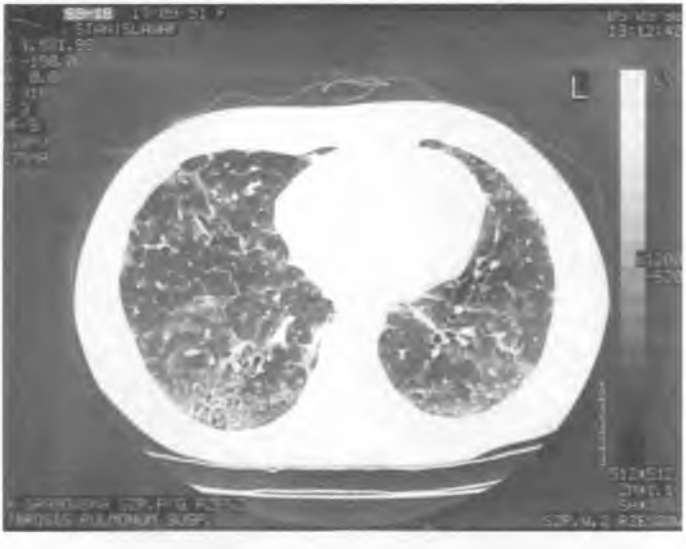

Fig. 2. Pneumoconiosis. Disseminated nodular changes with the presence of centrilobular and irregular patchy emphysema. Inhomogeneous densities in the posterior areas of the lungs

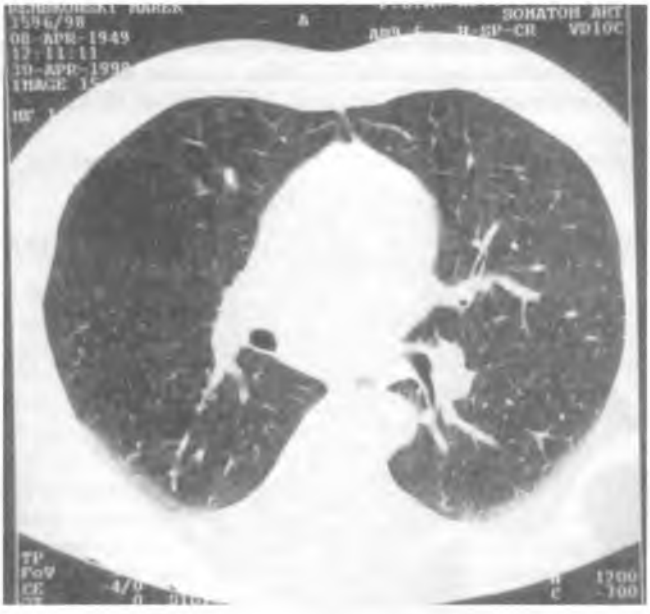

Fig. 3. Diffuse emphysematous areas, especially in the right lung. Reduction of the pulmonary markings. The hilar arteries are widened

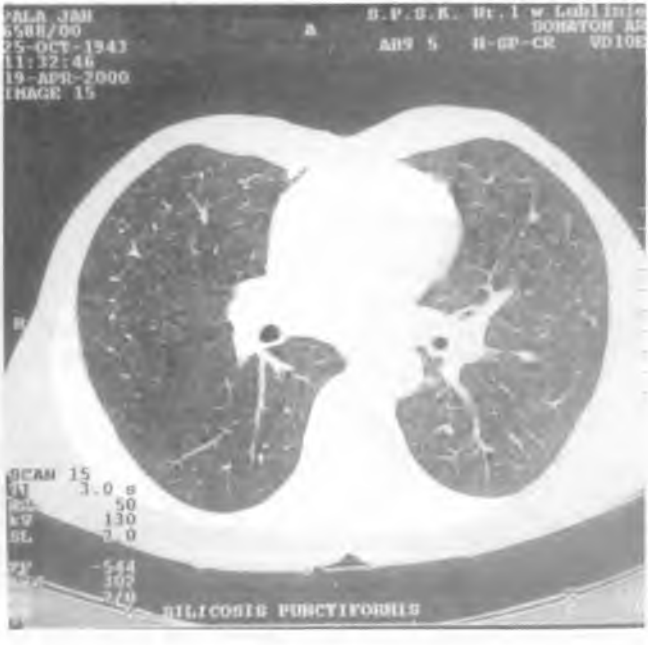

Fig. 4. Areas of patchy emphysema, also subpleural. Blurring of pulmonary markings

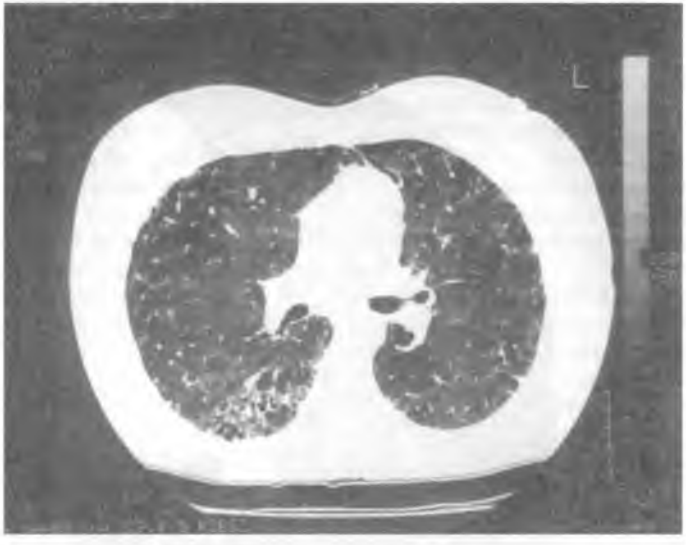

Fig. 5. Patchy emphysematous areas, reduction of the pulmonary markings, diffuse nodular changes. Inhomogeneous densities in the posterior areas of the right lung

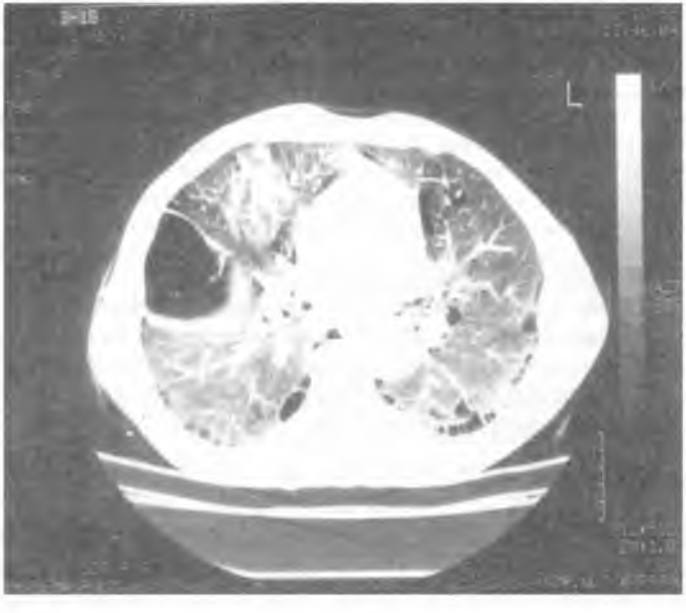

Fig. 6. Bullous emphysema on the right and subpleural on the left. Compressed lung parenchyma form ground glass opacities

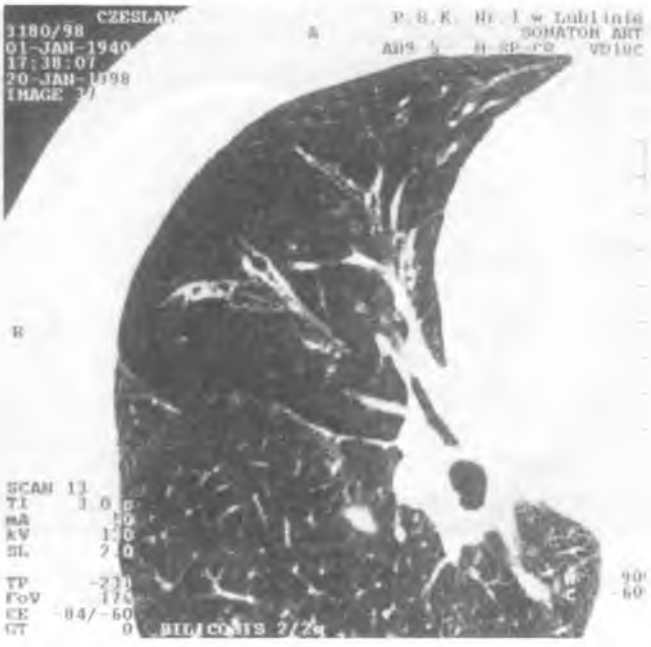

Fig. 7. Fibrosis as linear densities with emphysematous areas

emphysema were surrounded by irregular parenchymal fibrosis (Fig. 7). The presence of air-trapping was found in 8 patients. Physiological low increase in density along septa and in apical parts of the lower lobes was not classified as air-trapping. Scanning patients in the prone, supine and lateral positions reveals advantages of gravitational effect, intensifying the differences in density. The air-trapping was an important feature of HRCT. In 4 patients inhomogeneous lung density on inspiratory scans was emphasized on expiratory images. The density of air-trapping regions remains unchanged, while the normal lung parenchyma showed increased density on expiratory sections.

In the group of 45 patients the features of emphysema were found in 27 cases on plain radiographs, and in 38 patients on HRCT (differences highly statistically significant – McNemar's statistic χ^2=9.091; p=0.003). The presence of the air-trapping on the expiratory scans was found in 28 patients, while on plain radiograms it was suspected in 2 patients, the difference was highly statistically significant (McNemar's χ^2=24,038; p<0.001).

DISCUSSION

The emphysema and air-trapping are interstitial changes, causing inhomogeneous lung density on HRCT sections. Emphysema is usually a permanent destruction of lung parenchyma, while in the case of air-trapping the pathology may be potentially reversible. HRCT is considered to be the most accurate diagnostic modality in emphysema (2,10). The focal area of low attenuation are clearly seen among the areas of normal lung parenchyma of higher density, provided sufficiently low window level is established (-600 to –800 HU). The density of emphysematous bullas are usually below – 950 HU. In the areas of air trapping, the mean density is about – 786 ± 81 HU, while in the normal region increased densities are about – 673

±78 H.U. The mean differences was 113 – 165 H.U (4,23,24). The most frequent type is the centrilobular emphysema, of which the destruction of proximal parts of lobules is characteristic. It is the most often localized in the apical lung fields, in smokers with frequent chronic bronchitis, micronodules and areas of ground glass opacities (3,6,9,21,22).

The panlobular emphysema is predominantly distributed in lower lungs fields. In paraseptal emphysema fine linear densities, extending parallel to surface of the pleura, usually delineate the areas of parenchymal destruction. They dominate in the upper regions, and are not routinely connected with intense fibrosis. They usually form one layer. Differentiation with honeycombing cysts is based on the luck of distortion of the normal lobular architecture, fibrosis and parabasal localization (24).

The emphysematous bulla with diameter of 1 cm or larger usually has 1 mm thick walls. They are usually accompanied by centrilobular or paraseptal emphysema. Subpleural bullas often represent the presents of paraseptal emphysema. In bullous emphysema dominate bullas with diameter of 2-8 cm (2,24). The air trapping form areas of decreased lung density, without (or without normal) density increase on expiratory scans (2,5,7,18,19). The air trapping were found in 50–80% patients, 47% of whom were with normal radiograms (9).

There is a correlation between the amount of retained air and irreversibility of small airways pathology, corresponding with destruction of their most peripheral segments. The areas of air trapping may be invisible in standard HRCT examination, performed on hold full inspiration, which makes it necessary to perform additional sections on inspiration (8,13,21). The causes of air trapping are usually bronchitis and bronchiolitis obliterans with peribronchial fibrosis and loss of elasticity of their walls, inhalation of dusts, collagen-vascular diseases, bronchiectasis, cystic-fibrosis (12,16,17).

The expiratory sections differentiate causes of inhomogeneous lung densities, due to emphysema, interstitial pneumonia with ground glass opacities, vascular changes causing mosaic perfusion (1,12,14,20,24). In cases of inhomogeneous lung density caused by ground glass opacities in infiltrative lung diseases, both regions of higher and lower density show increases in the density on expiratory sections (1). The mean difference in densities on expiratory section was about 163 HU.

CONCLUSIONS

The HRCT sections statistically significantly increased the frequency of diagnosis of emphysema on inspiratory sections, and air-trapping on expiratory scans. In revealing of air-trapping HRCT is diagnostic modality of choice. The expiratory sections reveal the presence of air-trapping invisible on expiratory scans. The HRCT section enables differentiation of different kinds of emphysema that were invisible on plain radiograms, sensitivity of which in revealing small emphysematous changes is very poor. HRCT makes it possible to quantify emphysematous changes, the degree of parenchymal destruction, secondary functional disorders. It is more sensitive and specific in determining the type and extension of emphysema.

REFERENCES

1. Arakawa H. et al: Inhomogeneous Lung Attenuation at Thin-Section CT: Diagnostic Value of Expiratory Scans. Radiology, 206, 89, 1998.

2. Austin J. et al: Glossary of Terms for CT of the Lungs: Recommendations of the Nomenclature Committee of the Fleischner Society. Radiology, 200, 327, 1996.
3. Baldi S. et al: Relationship between Extent of Pulmonary Emphysema by High-Resolution Computed Tomography and Lung Elastic Recoil in Patients with Chronic Obstructive Pulmonary Disease. Am. J. Respir. Crit. Care. Med., 164, 585, 2001.
4. Bankier A. et al: Pulmonary Emphysema: Subjective Visual Grading versus Objective Quantification with macroscopic Morphometry and Thin-Section CT Densitometry. Radiology, 211, 851, 1999.
5. Choi S. et al: Lateral decubitus HRCT: a simple technique to replace expiratory C in children with air trapping. Pediatr. Radiol., 32, 179, 2002.
6. Erkinjuntti-Pekkanen R. et al: Long-term Risk of Emphysema in Patients with Farmer's Lung and Matched Control Farmers.Am. J.Respir.Crit.Care.Med.,158, 662, 1998.
7. Fotheringham T. et al: A Comparison of Method for Enhancing the Detection of Areas of Decreased Attenuation on CT Caused by Airways Disease. J Comput. Assist. Tomogr., 23, 385, 1999.
8. Gevenosis P. et al: Pulmonary Emphysema: Quantitative CT during Expiration. Radiology, 199, 825, 1996.
9. Grenier P. et al: New frontiers in CT imaging of airway disease. Eur. Radiol., 12, 1022, 2002.
10. Gurney J. et al: Regional Distribution of Emphysema: Correlation of High Resolution CT with Pulmonary Function Tests in Unselected Smokers. Radiology, 183, 457, 1992.
11. Kalaciński W. et al: Ocena zmian miąższu płucnego u 13-letniego chłopca na podstawie tomografii komputerowej o wysokiej rozdzielczości. Pediatria Polska, LXXI, 549, 1996.
12. Kauczor H-U. et al: Focal air-trapping at expiratory high-resolution CT: comparison with pulmonary function tests. Eur. Radiol., 10, 1539, 2000.
13. Kauczor H-U. et al: CT attenuation of paired HRCT scans obtained at full inspiratory/expiratory position: comparison with pulmonary function tests. Eur. Radiol., 12, 2757, 2002.
14. Klain J. et al: High-resolution diagnosis of emphysema in Symptomatic Patients with Normal Chest Radiographs and isolated Low diffusing Capacity. Radiology, 182, 817, 1992.
15. Kohlhäufl M. et al: Noninvasive Diagnosis of Emphysema. Aerosol Morphometry and Aerosol Bolus Dispersion in Comparison to HRCT.Am. J.Respir.Care.Med.,160,913, 1999.
16. Kubo K. et al: Pulmonary Infection with Mycobacterium Avium-intracellulare Leads to Air Trapping Distal to Small Airways. Am. J. Respir. Crit. Care. Med., 158, 979, 1998.
17. Laurent R. et al: Functional significance of air trapping detected in moderate asthma. Eur. Radiol., 10, 1404, 2000.
18. Lee K. et al: Correlation of Aging and Smoking with Air Trapping at Thin-Section CT of the Lung in Asymptomatic Subjects. Radiology, 214, 831, 2000.
19. Lucidarme O. et al: Evaluation of Air Trapping at CT: Comparison of Continuous-versus Suspended-Respiration CT Techniques. Radiology, 216, 768, 2000.
20. Müller N., Miller R.: Ground Glass Attenuation, Nodules, Alveolitis and Sarcoid Granulomas. Radiology 189, 31, 1993.
21. Tanaka N. et al: Paired inspiratory-expiratory thin-section CT findings in patients with small airway disease. Eur. Radiol., 11, 393, 2001.
22. Tonelli M. et al: HRCT Evident Fibrosis in Isolated Pulmonary Emphysema. J. Comput. Assist. Tomogr., 21, 322, 1997.
23. Verschakelen J. et al: Expiratory CT in cigarette smokers: correlation between areas of decreased lung attenuation, pulmonary function tests and smoking history. Eur. Radiol. 8, 1391, 1998.
24. Webb W. R., Müller N. L., Naidich D. P.: High-Resolution CT of the Lung. Lipincott-Raven 1996.

SUMMARY

Conventional computed tomography has several limitations, connected with long scanning time, and using 1 cm thick collimation. Improvement in quality of images of lung parenchyma led to the development of high resolution computed tomography (HRCT). It optimizes the morphological images of the lung parenchyma at the level of the lung lobule, becoming the modality of choice in evaluating the lung interstitium. The aim of the study was assessment of the usefulness of HRCT in diagnosis of emphysema, determining its character and presence of air-trapping. The emphysema and air-trapping are interstitial changes, causing inhomogeneous lung density on HRCT sections. Emphysema is usually a permanent destruction of lung parenchyma, while in the case of air-trapping the pathology may be potentially reversible. HRCT is considered to be the most accurate diagnostic modality in emphysema. The focal areas of low attenuation are clearly seen among the areas of normal lung parenchyma of higher density, provided sufficiently low window level is established (-600 to -800 H.U.). The HRCT sections statistically significantly increased the frequency of diagnosis of emphysema on inspiratory sections, and air-trapping on expiratory scans. In revealing of air-trapping HRCT is diagnostic modality of choice. The expiratory sections reveal presence of air-trapping invisible on expiratory scans. The HRCT section enables differentiation of different kinds of emphysema that were invisible on plain radiograms, sensitivity of which in revealing small emphysematous changes is very poor. HRCT makes it possible to quantify emphysematous changes, the degree of parenchymal destruction, secondary functional disorders. It is more sensitive and specific in determining the type and extension of emphysema.

Diagnostyka rozedmy płuc i pułapek powietrznych w tomografii komputerowej wysokiej rozdzielczości

Klasyczna tomografia komputerowa ma ograniczenia, które nie pozwalają na pełną i wiarygodną ocenę chorób śródmiąższowych płuc. Związane to jest z długim czasem skanowania, który w pierwszych skanerach wynosił do 18 sekund oraz z użyciem 1-cm kolimacji. Próby poprawy jakości uzyskiwanych obrazów miąższu płucnego doprowadziły do rozwoju techniki, nazywanej tomografią komputerową wysokiej rozdzielczości (TKWR). TKWR jest metodą obrazowania, która ma na celu uzyskanie optymalnej jakości obrazów struktur anatomicznych płuc i stała się metodą z wyboru w ocenie miąższu. Celem pracy jest ocena użyteczności tomografii komputerowej wysokiej rozdzielczości w diagnostyce rozedmy płuc, określeniu jej charakteru i obecności pułapek powietrznych. Pułapki powietrzne i rozedma płuc należą do zmian miąższu płucnego, powodujących obrazy niejednorodnej gęstości płuc na skanach TKWR. Rozedma płuc zwykle przedstawia nieodwracalną destrukcję miąższu płucnego, a w przypadku obecności pułapek powietrznych, patologia będąca ich przyczyną może być potencjalnie odwracalna. TKWR jest uznawana za najdokładniejszą technikę obrazowania rozedmy płuc. Ogniskowe obszary bardzo niskiej gęstości są łatwo widoczne w TKWR na tle normalnego, o wyższej gęstości, miąższu płuca otaczającego obszary rozedmy, jeżeli zastosowane są wystarczająco niskie ustawienia poziomów okna (-600 j. H. do -800 j. H.). Przekroje TKWR statystycznie istotnie zwiększają częstość rozpoznawania rozedmy płuc na przekrojach wdechowych oraz obecność pułapek powietrznych na przekrojach wydechowych. W wykrywaniu obecności pułapek powietrznych TKWR jest metodą diagnostyczną z wyboru. Wydechowe przekroje wykrywają obecność pułapek powietrznych niewidocznych na przekrojach wydechowych. Przekroje TKWR umożliwiają różnicowanie różnych rodzajów rozedmy płuc, niewidocznych na zwykłych radiogramach, których czułość w wykrywaniu małych zmian rozedmowych jest bardzo niska. TKWR umożliwia jakościową ocenę zmian rozedmowych, stopnia destrukcji miąższu, wtórnych zaburzeń czynnościowych. Jest bardziej czuła i specyficzna w określaniu typu i rozległości rozedmy.