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Bronchiectasis and lung cavities: the impact on emphysema quantification

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Бронхоэктазы и полости легких: влияние на количественную оценку эмфиземы

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Summary

Background. In this study we tried to assess the impact of lung cavities and bronchiectasis on the quality of AI-based emphysema analysis. **Methods.** A retrospective analysis of chest CT of 50 patients with emphysema combined with lung cavities and bronchiectasis was performed. All studies were evaluated on the same machine with standard technical parameters. Each examination underwent AI-based lung segmentation process and also was assessed by two independent radiologists for visual correctness. Thresholds of –950 HU and –930 HU were used for emphysema evaluation. **Results.** Programs A and C was capable of defining emphysematous changes starting from 0.2% and program B from 0.3%. Differences in program calculations in one patient ranged from 0 to 17.6%. In 49 out of 50 patients we found bronchiectasis which was included in the final AI-calculations in 100% when analysed by all three programs. Lung cavities were present in 19 out of the 50 patients and in most cases they were considered by programs as areas of emphysema, yet slightly better results were given by program B. A significant overstatement of the estimated emphysema volume presented in program B calculations was discovered, while the results of programs A and C fell within the confidence interval. **Conclusions.** Lung cavities and bronchiectasis in complex with emphysema significantly affect the result of AI-based analysis. When comparing three software products, there was found a significant overestimation by program B, with a good correlation between programs A and C.

Key words: bronchiectasis, lung cavity, emphysema, artificial intelligence, computed tomography

Резюме

Цель. В этом исследовании мы пытались оценить влияние полостей легких и бронхоэктаза на качество анализа эмфиземы на основе ИИ. **Материалы и методы.** Был проведен ретроспективный анализ КТ грудной клетки у 50 пациентов с эмфиземой в сочетании с полостями деструкции в легких и бронхоэктазами. Все исследования оценивались на одном томографе со стандартными техническими параметрами. Каждое обследование проходило процесс сегментации легких на основе ИИ, а также было оценено двумя независимыми рентгенологами на предмет правильности картирования. Пороги –950 HU и –930 HU использовали для оценки эмфиземы. **Результаты.** Программы A и C были способны определять эмфизематозные изменения, начиная с 0,2%, и программа B от 0,3%. Различия в программных расчетах у одного пациента варьировались от 0 до 17,6%. У 49 из 50 пациентов мы обнаружили бронхоэктазы, которые были включены в окончательные расчеты в 100% при анализе по всем трем программам. Полости деструкции в легких

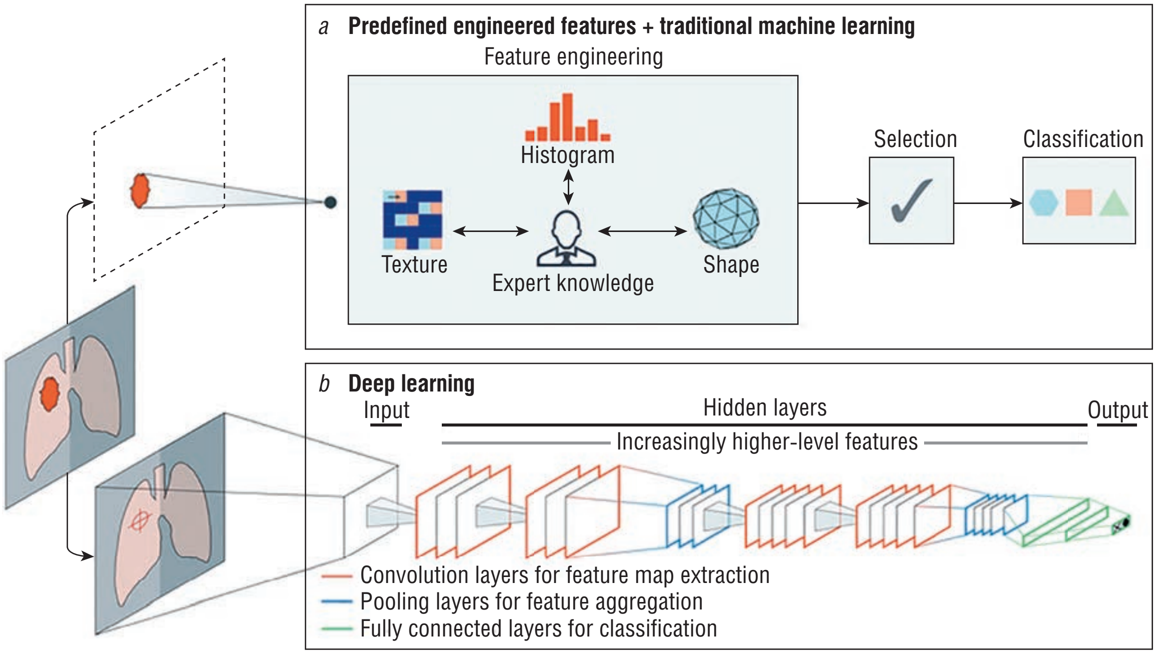

Fig. 1. Diagnosis of lung tumours by means of different methods of processing medical AI images [4]. *a* — The first method is based on analysis of a characteristic whose parameters are extracted from the area of interest based on expert knowledge. Examples of these features in the characterization of lung cancer include tumour volume, shape, texture, intensity, and localization. The most reliable parameters are selected and included in classifiers machine learning. *b* — The second method uses deep learning and does not require clear marking of the area of interest — localization is usually enough. Program covers several layers where a feature is detected, selection and final classification is performed simultaneously during training. As layers study more and more high-level objects, earlier layers can study abstract forms such as lines and shadows, while other more deep layers can study entire organs or objects. Both methods fall under radiomics, a data-driven research area based on radiology

присутствовали у 19 из 50 пациентов, и в большинстве случаев они были рассмотрены как участки эмфиземы.

Ключевые слова: искусственный интеллект, эмфизема легких, бронхоэктазы, полости деструкции

Introduction

Nowadays there are many studies dedicated to automatic quantification of lung emphysema. However, none of them takes into consideration its combination with lung cavities and bronchiectasis and their impact into the final calculations.

Currently the most widely used technique in medical image analysis is convolutional neural networks (CNN) [1–3]. A typical CNN contains a series of layers that sequentially display input image data to desired endpoints while studying more and more high-level imaging functions. Starting with Input images, «hidden layers» in CNN usually include a sequence rollup and merge operations that extract object maps and perform aggregation of objects, respectively. Then these hidden layers are followed by fully connected layers providing high-level reasoning before then the output layer will give predictions. CNNs often receive end-to-end training with marked data for monitored training (Fig. 1) [4].

Recently, many companies presented their programs for lung imaging, segmentation and emphysema quantification. In our study we tried to compare three of such programs.

Study population

Data from a total of 87 patients who underwent unenhanced chest CT were retrospectively analysed. Inclusive criteria were:

- full unenhanced chest computed tomography (CT) data in DICOM format;
- presence of lung emphysema confirmed by two independent radiologists;
- presence of bronchiectasis or lung cavities.

We excluded 28 patients because of previous thoracic surgery, 7 had massive regions of consolidation, in 2 patients emphysema was a result of an α1-antitrypsin deficiency. Thus, the final study population consisted of 50 patients.

Study protocol

Imaging protocol. CT studies were performed on Toshiba Aquilion 32 and AQUILION PRIME with slice thickness of 1.0 mm, Spiral Pitch Factor- 0.84, kVp (peak x-ray voltage) — 120 kV, rotation time –0,5 s. Reconstructions were made using convolution Kernel FC07. Those were the standard parameters set by the manufacturer.

Image analysis. Three different programs (coded A, B, C) for automated lung segmentation and emphysema volume measurement in percent/litres with visual colour mapping were used. As a pre-processing step of the segmentation, the bronchial bifurcation landmark was manually put.

After AI-based lung segmentation, two radiologists visually independently assessed the same examination.

At first, we used a commonly used threshold for emphysema of –950 HU. However, after visual comparison of colour mapping and CT images it was found that the threshold of –930 HU gives a better view of emphysema so it was also added to an analysis.

Statistical Analysis. Statistical analyses were conducted using SPSS (2020). Correlations between the results of the quantification analysis by all three programs were assessed using the Pearson correlation coefficient, the significance level was taken less than 5%.

Results

A total of 50 patients (20 women, mean age±SD of 50.78±14.4 years [range, 23–89 years]; 30 men, mean age of 50.54±14.3 years [range, 25–80 years] who underwent chest CT were retrospectively included.

The minimum percentage of detected changes for programs A and C was 0.2%, for program B — 0.3%. Differences in program calculations in one patient ranged from 0 to 17.6%.

Out of the 50 patients included in our study, lung cavities were found in 19 cases. And as we can see from Table they were seen by programs as an areas of emphysema. Though program B gave a slightly better result in comparison to programs A and C.

Table

Amount of the cavities determined as emphysema by three programs

Program	Lung cavities
A (n)	11 (19)
B (n)	9 (19)
C (n)	13 (19)

Bronchiectasis were determined in 49 out of 50 patients and as well were interpreted as an emphysema in 100% by all three programs.

The linear dependence of the percentage of lung emphysema calculated by the programs (Figure 2) revealed their high specificity. Because of an abnormal distribution of acquired data, Pearson's criteria instead of Student's criteria was chosen. The rank correlation coefficient was 0.993-0.995 demonstrating a good correlation between results of all three programs.

Then we analysed the difference of the results of calculations in one patient based on the emphysema volume (Fig. 3).

Discussion

Emphysema quantification has been a topic of interest for many years due to the labour-intensive process

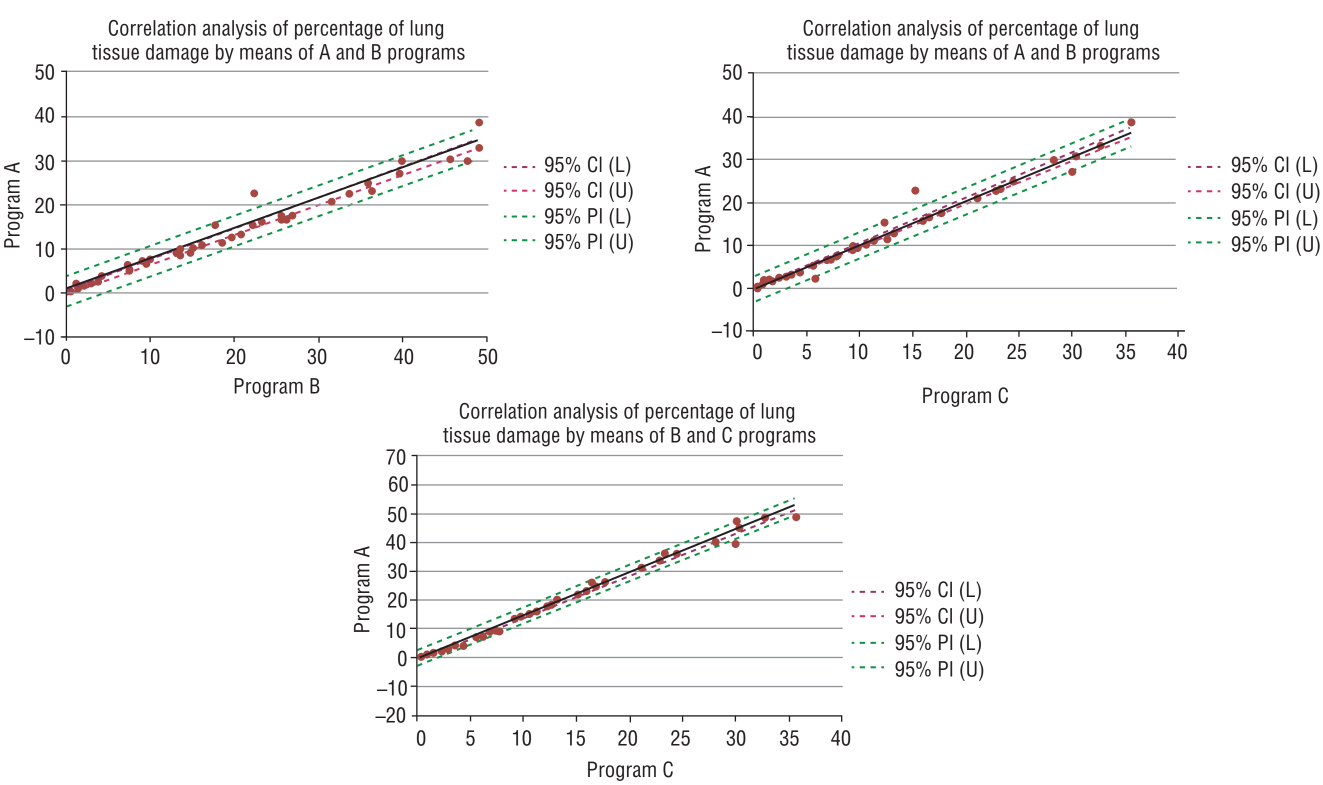

Fig. 2. Correlation analysis of percentage of lung tissue damage by means of A, B and C programs. CI — 95% Confidence interval, PI — 95% Predicted interval Y — trend line

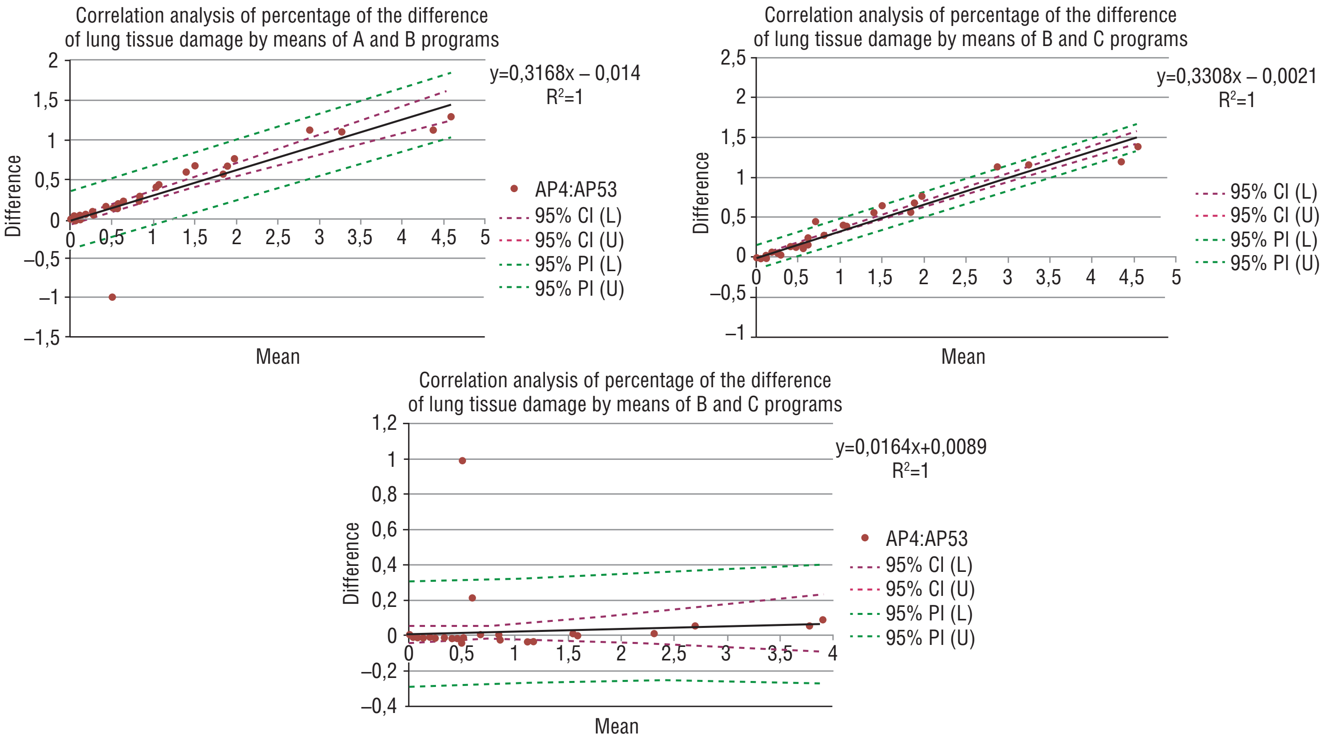

Fig. 3. Correlation diagrams of the programs A, B and C assessment results difference (percentage of lung tissue damage). CI — 95% Confidence interval, PI — 95% Predicted interval, Y — trend line. R^2– the approximation reliability value, 0.3389 (A), 0,3539 (B), 0,0164 (C) — the deviation coefficient

and subjectivity of visually quantifying emphysema [6, 8, 9, 11]. Compared with spirometry values, imaging provides additional insight into the pathologic changes that directly contribute to airway obstruction. Pulmonary emphysema, which is defined by the thickening of the bronchial wall and increased air retention by way of air trapping, is the most important pathologic change in the CT thorax when evaluating increased mortality [5, 7, 10].

A commonly used threshold of lung emphysema is currently –950 HU [6]. But different values of absorption coefficient in the range from –910 HU to –980 HU were used when developing automated volumetric assessment programs [12, 13]. In our study all chest CT were visually compared with the results of the AI-based colour mapping and it showed that with the threshold of -930HU areas of emphysema were pointed out more correctly. This may be a result of software settings, or it may be an effect of scan parameter settings. This problem requires further investigation, but this fact should be taken into account when using such programs and adjust the threshold setting manually comparing the results with the changes visualized by the human eye.

We can speculate that our study, performed in one centre, on the same equipment can be used to assess different AI tools in determination of emphysema. As far as we know, all of the earlier studies about emphysema quantification have been focused on one particular program, usually created specifically for the study [6–9, 11]. We thought that comparison of different programs could provide a better understanding of AI abilities in detecting emphysema in general and also give us a view on how comparable the results of such analysis would be. For our study we chose two commercial programs which were part of the tomograph software (A, C) and one free of charge program that can be downloaded and installed on any computer (B).

It showed that although all of the three programs showed great capability of detecting emphysema there are still limitations to a segmentation process, such as bronchiectasis and cavities. We also found out that program B gave a significantly higher percentage of emphysema compared to the other two programs. Moreover, the increase in the emphysema percentage led to even more significant the difference. The other two programs showed good correlation among themselves. We can speculate that it happened because of the inclusion of the lung cavities and bronchiectasis into the analysis.

However, it is also crucial to note the limitations of our study. The format of our study is retrospective. Therefore, no data on emphysema follow-up in our patient population were evaluated.

Limitations. It was a single-centred study and we've assessed a relatively small amount of patients.

Conclusion. All of the three used programs showed a good capability in recognition of emphysema and strong correlation between the final results of the quantification, though the program B gave a significantly higher percentage of lung tissue damage. And in all cases the cavities and bronchiectasis had a significant impact on the analysis.

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