Diagnostic value of chest CT scanning for determination of Covid-19 severity in individual lung lobes

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INTRODUCTION

Chest CT scan has a very high sensitivity and low specificity in detecting SARS-CoV2 infection [1, 2, 3]. The CT exam with a positive PCR test is an important diagnostic tool in the assessment of the severity of the infection and course of the disease. Most authors show that typical radiological symptoms of Covid-19 infections are ground-glass consolidations, crazy paving, vascular dilatation, traction bronchiectasis, and subpleural bands [1, 2, 3]. Many studies report that SARS-CoV2 infection is more common peripherally and bilaterally. Several studies have investigated the relationship between the distribution of the disease symptoms between the upper and lower zones [4]. To our knowledge, there are only a few reports on the distribution of pathological changes in the course of SARS-CoV2 infection in relation to the anatomical division of lung lobes [5, 6]. Computed tomography perfectly reflects the anatomic boundaries of the lung lobes and facilitates identification of the specific Covid-19 radiological changes in the particular lobes. The lobes of the lungs differ anatomically in terms of the course of the bronchi and have varied ventilation [7]. Therefore, we considered it interesting to examine whether the anatomical boundaries of the lungs contribute significantly to the distribution of radiological changes in the course of SARS-CoV2 infection.

The aim of the study was to evaluate the degree and frequency of involvement of individual lung lobes and the population Lobe Involvement Coefficient (pLIC) value in the investigated population.

MATERIALS AND METHOD

The study population comprised hospital patients in the Łańcut Medical Centre in the Subcarpathian Province of southeast Poland, confirmed to be infected with SARS-CoV2 by positive PCR test. Patients with known coexisting diseases which can present similar imaging abnormalities, including interstitial lung diseases and congestive heart failure, were excluded from the final analysis.

Radiological data were collected from obligatory chest CT examinations of all patients infected with the SARS-CoV2 virus performed at the VOXEL Department of Radiology in the Łańcut Medical Centre. CT scan was performed immediately after diagnosis.
The analyzed material consisted of 124 patients aged 18–92 years (mean age: 55.99, SD: 16.99). The study covered 69 men aged 27–89 years (mean age: 54.86, SD: 17.14) and 55 women aged 18–92 years (mean age: 67.42, SD: 16.86).

CT examinations of the chest were performed on a GE 16- and 32-row CT LightSpeed apparatus, with the spiral technique in 2.5 mm thick axial sections (continuous layers) reconstructed to a thickness of 1.25 mm (pulmonary reconstruction) with the high-resolution HRCT reconstructive algorithm. Retrospective analysis of each chest CT examination was performed by consensus between two radiologists.

The most common symptom was the ground-glass opacification, which alone accounted for 41.1%, and with consolidation a further 35.5% of the total number of respondents. In addition, in the examined material frequent symptoms were thickening of the interlobular septa (53.2%) and crazy paving (41.9%), as well as areas of consolidation (40.3%).

In the spatial distribution of typical Covid-19 pathological changes was analyzed in five lung lobes: right upper lobe (RUP), right middle lobe (RML), right lower lobe (RLL), left upper lobe (LUL), and left lower lobe (LLL). The degree of severity of lobe involvement was classified based on a five-point scale, following the adapted Radiographic Assessment of Lung Edema score proposed by Warren et al. [8]:

- **Score 0** – no radiological changes.
- **Score 1** – radiological changes typical for Covid-19 infections covering up to 25% of the lobe area.
- **Score 2** – radiological changes typical for Covid-19 infections covering 26–50% of the lobe area.
- **Score 3** – radiological changes typical for Covid-19 infections covering 51–75% of the lobe area.
- **Score 4** – radiological changes typical for Covid-19 infections covering more than 75% of the lobe area.

Each lobe was assessed using the score scale from 0–4 points for a single patient and from 0–496 points for the entire study population.

In order to standardize the comparison between individual lobes, the definition of the population Lobe Involvement Coefficient (p-LIC) was introduced, an index invented by authors. This coefficient defines the mean severity of involvement of a particular lobe for the entire study population. P-LIC was calculated according to the formula: sum of points of the severity of particular lobe involvement according to the above-mentioned five-point scale/number of analyzed lobes. This showed the average number of points for a given lobe in the studied population.

In an individual assessment of a single patient, a percentage of the involvement of individual lobes or the entire lung parenchyma in general is sufficient. However, when considering the frequency and intensity of a particular lobe involvement in the entire population, it is difficult to assess the percentage of individual lobe involvement in the entire study population. On the other hand, it seems that the p-LIC coefficient can be useful in such an analysis and allow for an objective and repeatable assessment, both in the initial diagnosis and, for example, when monitoring the treatment of a given population.

Statistical analysis. Performed with the use of Statistica 10.0 software. The values of the parameters measured – measured on an ordinal scale – were characterized using the number and percentage. Anova Friedman’s test was used to compare the five individual lobes assessed in each subject according to the ordinal scale of the measurement. After the differences were found to be significant, Dunn’s post hoc test was used to compare the individual pairs of lobes. A 5% inference error was assumed, and therefore a significance level of p <0.05 indicating the existence of statistically significant differences [9].

RESULTS

The degree of the severity of lobe involvement was classified in a five-point scale described in detail in the Materials and Method section.

Table 1 presents the cumulative number of points obtained for individual lobes in the entire examined population and the calculated population Lobe Involvement Coefficient (p-LIC).

| Right Lobe | Left Lobe | Right Middle Lobe | Right Lower Lobe | Left Lower Lobe |
|------------|-----------|-------------------|------------------|----------------|
| Sum of points for a given lobe in the five-point scale of lobe involvement | 121 | 128 | 99 | 170 | 167 |
| Population Lobe Involvement Coefficient (pLIC) | 0.976 | 1.032 | 0.798 | 1.371 | 1.347 |

Figure 1 presents the chest CT of a patient with COVID infection with a relatively uniform involvement of both the lower and upper lobes, and relative saving of the middle lobe.
The obtained results revealed a more severe course of infection in the left and right lower lobes of lungs. The middle right lobe exhibited a relatively low degree of destruction compared to the others.

The introduced p-LIC shows these dependencies in relation to a particular lobe. P-LIC defines the mean severity of particular lobe involvement in the entire study population. Descriptive statistical data of the investigated population are shown in Table 2 and Figure 2.

Table 2 presents the severity of involvement of the individual lobes in the entire examined population in a five-point severity scale.

| Severity of the lobe involvement | Right Upper Lobe | Left Upper Lobe | Right Middle Lobe | Right Lower Lobe | Left Lower Lobe |
|---------------------------------|------------------|-----------------|-------------------|-----------------|----------------|
| 0                               | 49 (39.5%)       | 43 (34.7%)      | 53 (42.7%)        | 32 (25.8%)      | 35 (28.2%)     |
| 1                               | 47 (37.9%)       | 55 (44.4%)      | 56 (45.2%)        | 44 (35.5%)      | 47 (37.9%)     |
| 2                               | 15 (12.1%)       | 9 (7.3%)        | 5 (4.0%)          | 30 (24.2%)      | 20 (16.1%)     |
| 3                               | 8 (6.5%)         | 13 (10.5%)      | 7 (5.6%)          | 6 (4.8%)        | 8 (6.5%)       |
| 4                               | 5 (4.0%)         | 4 (3.2%)        | 3 (2.4%)          | 12 (9.7%)       | 14 (11.3%)     |

Lobes with a lower p-LIC score were found to show more often a milder course of infection according to the Radiographic Assessment of Lung Edema score scale. Statistically significant differences in the involvement between most of the individual lobes were shown. There was no statistically significant difference in the degree of lobe involvement between the left and right upper lobes, nor the left and right lower lobes (Tab. 3).
There are reports in the literature on lung ventilation models, which report that the lower lobes have a greater volume and therefore a higher flow rate. Perhaps this determines the greater severity of the involvement of these lobes [7]. Similar results were reported by other authors describing frequent involvement of the lower lobes [3, 5, 13, 14].

An interesting observation is the fact that the middle lobe is affected by the disease relatively least severely – p-LIC 0.798. A detailed analysis indicated that this lobe was most often assigned involvement severity scores 0 and 1. The same researchers working on a five-lobe lung ventilation model noticed the lowest frequency of detachment of microfluidic bodies with diameters of 0.01 μm and 10 μm in the middle lobe. Similar results were shown by other authors, i.e. relatively lighter involvement of the central lobe in the course of Covid-19 [3, 12, 14].

Most original papers and meta-analyses report a similar percentage distribution of the infection severity in individual lobes [3, 5, 13, 14]. Nevertheless, it is usually only one of the many aspects assessed without a detailed analysis of this feature. To the best of our knowledge, no statistic significance of the distribution differences has been reported so far. We believe that our work is a valuable supplement to our earlier observations, and that the introduced pILC is a useful quantitative indicator of lobe involvement for the entire study population, not only for individual patients.

This study has several limitations. The first is the size of the group. Similar analyses should be carried out on a larger population to verify the proped theses. Another limitation is the selection of the group. Our patients were examined in the early stages of infection. Hence, it is not known whether the distribution of the lobe involvement indicated will persist unchanged during the evolution of Covid-19 disease.

CONCLUSIONS

CT examination can be a very useful tool for assessing severity in the course of SARS-CoV2 infection. The introduced pILC index allows a quantitative assessment of the involvement of individual lobes in relation to the entire studied population. The lower lobes are affected most frequently and most severely, with no statistical difference between the right and left sides. The middle lobe is affected relatively least frequently and lightly.

Ventilation mechanisms dependent on the anatomical structure of individual lobes of the lungs may contribute significantly to the distribution of changes in the course of Covid-19 disease.

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