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Lung ultrasonography and computed tomography comparison in convalescent athletes after Sars-CoV-2 infection – a preliminary study

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Keywords

lung ultrasonography;
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Abstract

Background: The assessment of elite athletes after SARS-CoV-2 infection gives rise to doubts concerning return-to-play decisions: what period of convalescence is needed and what diagnostic measures are appropriate. While cardiovascular protocols have been widely discussed in the literature, lung parenchyma imaging was only briefly mentioned, and the usefulness of lung ultrasound has been not considered yet. **Materials and methods:** A total of 31 elite Caucasian male athletes (mean age: 26.03 ± 5.62), recovered from COVID-19 were assessed after SARS-COV-2 infection. Medical data was collected. Lung ultrasonography and high-resolution computed tomography were performed. **Results:** Normal lung parenchyma dominated on CT scans. A total of 25 athletes (80.6%) presented abnormalities on high-resolution computed tomography; changes typical for COVID-19 were detected in five cases (16.1%), and less specific abnormalities were identified in 20 athletes (64.5%). Despite the prevalence of ultrasound abnormalities, A-line pattern was dominant in 23 athletes (74.2%): for 434 ultrasound-scans, it was visible in = 265 (61.1%). In 93.2% of the subjects, it corresponded to a normal lung parenchyma pattern visible on high-resolution computed tomography. The sensitivity of lung ultrasonography in comparison to high-resolution computed tomography was 74.65%, while the specificity was 68.56%. **Conclusion:** Lung changes are frequent, but not extensive. Ultrasound A-line pattern was associated with normal lung parenchyma findings revealed on high-resolution computed tomography. The negative predictive value for lung ultrasonography (93.2%) points towards its suitability in return-to-play protocols.

Introduction

The increasing number of patients after SARS-Cov-2 infection has led to questions concerning the scheme of screening after illness. The available diagnostic methods useful in the assessment of the impact of COVID-19 on the respiratory system include chest X-ray (CXR) and high-resolution computed tomography (HRCT)⁽¹⁻³⁾.

During the COVID-19 pandemic, lung ultrasonography (LUS), based on the assessment of the characteristic patterns of ultrasound artifacts⁽⁴⁻⁹⁾, became an attractive diagnostic tool, as it enables fast bedside assessment of lung parenchyma. While the results in the assessment of fibrosis (e.g. connective tissue changes) are promising⁽⁹⁾, it may also be useful for evaluating the resolution of lung involvement⁽¹⁰⁾.

The ultrasound abnormalities typical for active COVID-19 include:

- interstitial lung syndrome (B-lines: vertical artefacts arising from the pleural line);
- thickened, irregular, interrupted pleural line;
- inflammatory consolidations: peripheral, subpleural hypoechogenic areas with thin or thick C-lines. They may be: 1) small and round-shaped, 2) larger, sometimes with concomitant air or fluid bronchogram 3) massive, with whole lobe involvement, visible as a hypoechogenic area with tissue-like echotexture (hepatization)⁽¹¹⁾.

Italian researches have distinguished ultrasound patterns for:

1. LowLUS (low probability) – A-pattern with lung sliding without B-lines.
2. HighLUS (high probability) – presence of multifocal B-lines, light beams (hyperechoic bands), peripheral consolidations, irregular pleural line
3. IntLUS (intermediate probability – less typical pattern – unilateral isolated B-pattern with or without small consolidations
4. AltLUS (alternative probability) – a pattern more typical for another diagnosis, including isolated air consolidations, dynamic air bronchogram, pleural effusion, diffuse B-lines symmetrically increasing in the lower areas⁽⁸⁾.

Elite athletes are a unique population consisting of young people without comorbidities. While a fulminant or severe course of COVID-19 in this group is rather rare, persistent fatigue, weakness or prolonged presence of respiratory symptoms are frequent⁽¹²⁾. It should be underlined that this population varies from others because the goal after treatment is not to return to average physical activity, but competitive efforts. To increase the safety of the return-to-play (RTP) process, further assessment seems to be of value. While cardiological screening is widely described in the literature^(13–15), the need for respiratory assessment has only been briefly addressed^(13,16,17). In asymptomatic and mild-course cases, imaging of lung parenchyma is not obligatory^(13,16). In athletes hospitalized due to COVID-19 or in cases of persistent symptoms (>14 days), the first-choice imaging technique is CXR. In cases involving abnormalities or further clinical doubts, HRCT is recommended⁽¹³⁾. In selected cases, cardiopulmonary exercise test (CPET) should be performed^(13,18,19). LUS as a separate diagnostic method has not been mentioned in the RTP protocols yet, and it is probably the first study describing that possibility.

Materials and methods

Study group

A total of 31 Caucasian athletes representing different sports disciplines, including members of the Olympic Team, were examined between August 2020 and February 2021 before their return to full competitive activity. The convalescents were assessed after the isolation period, in

Tab. 1. Study group

Characteristics of study group	N = 31
Mean age, SD, (range)	26.0 ± 5.6 (17–38)
Height (cm)	190.3 (173–203)
Weight (kg)	86.6 (67–104)
Numbers of days after infection, SD (range)	28.8 ± 15.3 (11–50)
Sports discipline	n (%)
football	15 (48.4%)
rowing	10 (32.3%)
volleyball	5 (16.1%)
basketball	1 (3.2%)
Course of infection	n (%)
asymptomatic (-)	4 (12.9%)
mild symptoms (+)	17 (54.8%)
moderate symptoms (++)	9 (29.0%)
severe symptoms (hospitalization) (+++)	1 (3.2%)

a time interval ranging from 11 to 50 days (mean 28.83 ± 15.3 days) after infection. None of the participants had a history of chronic illness, recurrent infections, or drug use; no persistent symptoms were observed during examination.

There were 29 positive RT-PCR tests, and two cases were confirmed based on the presence of IgG SARS-CoV-2 antibodies after documented exposure (Tab. 1).

All patients were divided into four groups depending on severity of symptoms:

- (-) – asymptomatic;
- (+) – with mild symptoms (fatigue, weakness, low grade temperature, headache, arthromyalgia, sore throat, light cough without dyspnea, anosmia, ageusia) persisting for up to 7 days;
- (++) with moderate symptoms (fever >38 degrees, chest pain, dyspnea, desaturations <94%, tachycardia in afebrile periods or other symptoms lasting over 7 days – excluding anosmia and ageusia);
- (+++) hospitalized patients with desaturations <90%, requiring oxygen therapy.

Methods

The protocol adopted for the ultrasound examination was based on the scheme of 14 zones of the chest proposed by Italian researchers⁽⁷⁾ (Fig. 1). Areas with A-lines, B-lines, Z-lines, pleural abnormalities, and the number of consolidations were counted in each case. The sonographer was blinded to the results of HRCT.

The ultrasound system used was General Electric Vivid E95, with linear probe 9L, frequencies of 2.4–10 MHz. A special LUS preset was prepared: a single-focal point modality was applied, low mechanical index was maintained, and smooth filters and compound imaging were turned off. The images were obtained to a depth of 8 cm, and registered on 7s cycles. In a few cases, the obtained images were compared to the sector-probe (4Vc) visualization. The results

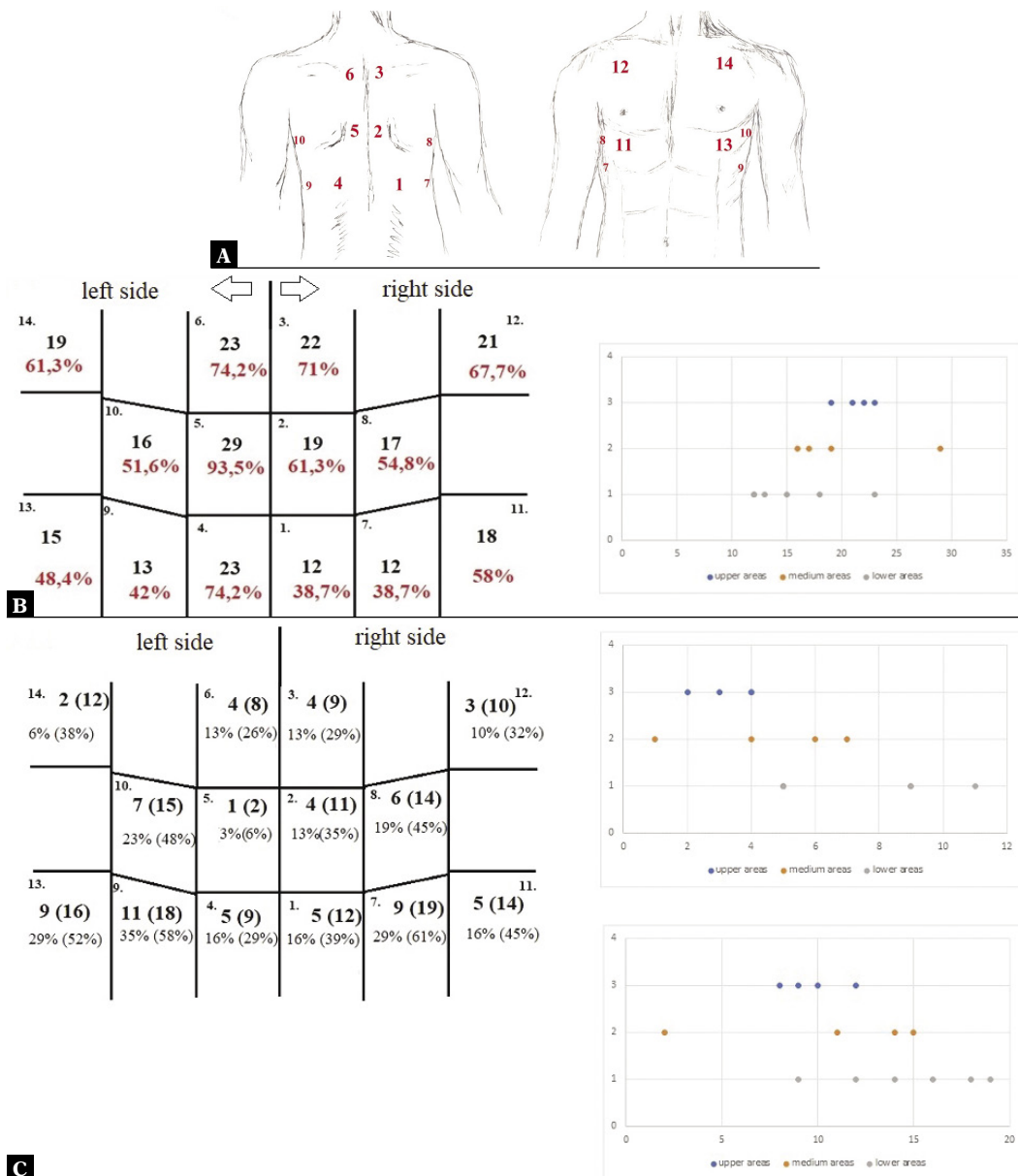


Fig. 1. The distribution of A-line pattern and LUS changes. **A.** The scheme of 14- anatomical scanning locations for ultrasound- places of probe applications. **B.** Distribution of the A-line artifacts. The number within each square refers to the amount of examinations with the only A-line artifacts in this localization (percentage value given in parenthesis, n=31). The data are presented in the diagram. **C.** Distribution of the ultrasound changes in the particular areas. First number within the square refers to the number of examinations with consolidations or B-pattern in the particular localization. The value within () refers to the all found changes in LUS (consolidations, B-pattern, pleura abnormalities, multiple Z-lines). Percentage values are given in () below. The data are presented in the diagrams.

were analyzed on an external computer (offline) using dedicated software (Echo PAC version 112; GE Healthcare, Wauwatosa, WI, USA).

Directly after ultrasound assessment, 64-sliced computed tomography (0.625 mm-slice thickness) on General Electric Revolution EVO system was performed.

The images were described by an experienced radiologist, unaware of the result of LUS. To ensure a better comparison of the two diagnostic methods CT images were also assessed in the 14-area scheme (434 images) corresponding to LUS.

Statistical methods

The processing of statistical data was performed using the software Statistica, version 10 (StatSoft, Tulsa, OK, USA). Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as percentage. The positive and negative predictive values were determined. The material for the study included medical test results of athletes, who were assessed before their return to normal competitive activity after SARS-Cov2 infection. The retrospective analysis was approved by the Ethics Committee (Decision No. AKBE/43/2021).

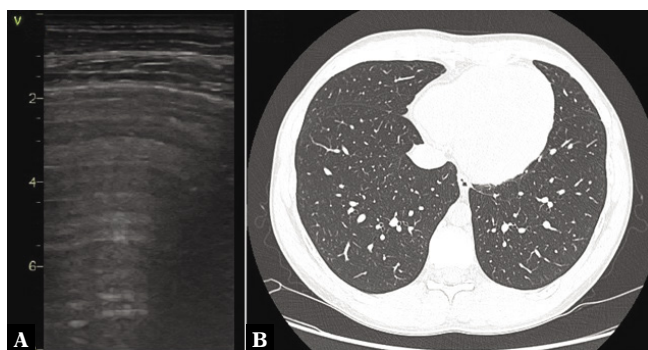


Fig. 2. The normal lung parenchyma. **A.** Ultrasound A-line pattern of the lungs corresponding with **B.** normal lung parenchyma visible in a high resolution computed tomography

Results

A total of 27 athletes (87.0%) were symptomatic, with mild symptoms reported in 17 athletes (54.8%), and moderate symptoms in nine (29.0%). Only one athlete (3.2%) had a severe COVID-19 course requiring hospitalization and low-flow oxygen therapy due to progressive dyspnea and desaturations. Four athletes were asymptomatic (12.9%). The patterns of changes visible on HRCT and LUS depending on the severity of symptoms are presented in Tab. 2.

LUS

Changes were found in all patients, and their distribution was significant (Fig. 1). The obtained LUS images revealed:

- A-line artifacts

The most frequent pattern was A-lines –horizontal reverberations of ultrasounds (Fig. 2), observed in 265 (61.0%) scanned areas. A total of 23 athletes (74.19%) had dominant A-pattern of the lungs. According to Tab. 2, the percentage of A-line areas was lower in the group, with more expressed symptoms.

- B-line artifacts

Tab. 2. Pattern of changes visible on LUS

	Total	Asymptomatic (-)	Mild (+)	Moderate (++)	Severe (+++)
Number of patients (N)	31	4	17	9	1
Number of assessed areas (N × 14)	434	56	238	126	14
Number of areas with A-line pattern (only)	265 (61%)	36 (64.3%)	151 (63.4%)	73 (57.9%)	5 (35.7%)
Number of patients with dominant A-line pattern* * A-pattern in ≥50% areas (percentage for each group)	24 (77.4%)	4 (100%)	14 (82.6%)	6 (66.7%)	0 (0%)
Number of patients with dominant "abnormal" pattern* * A-pattern in <50% areas (percentage for each group)	7 (22.6%)	0 (0%)	3 (17.6%)	3 (33.3%)	1 (100%)
Number of areas with consolidations	59	7 (12.5%)	29 (12.6%)	21 (16.7%)	2 (14.3%)
All consolidations	70	8	36	24	2
Index: consolidation per patient	2.3	2.0	2.1	2.7	2.0
1) Big consolidations with thick C-line	25	2	12	10	1
2) Small consolidations	45	6	24	14	1

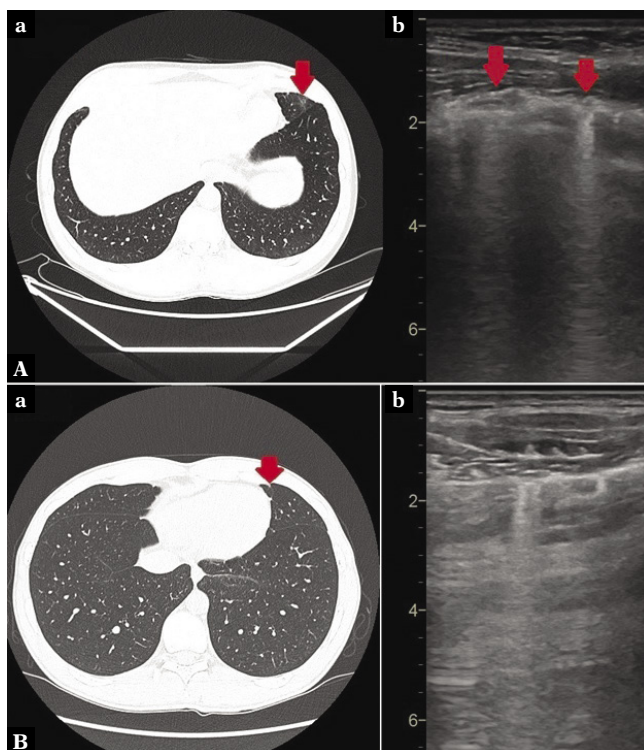


Fig. 3. A typical ultrasound view of Z-lines. **A.** First patient a) High resolution computed tomography: the small area of increasing density. b) Lung ultrasonography: two subpleural scarring changes with thick C-lines with two accompanying short, thin Z-lines. **B.** Second patient: a) High resolution computed tomography: small, subpleural adhesions. b) Lung ultrasonography a group of short, vertical Z-line artifacts

Only a few B-lines were observed. They appeared typically in the paradiaphragmatic areas and in that location post-inflammatory adhesions were subsequently identified on HRCT.

- Z-line and I-lines

The Z and I-lines refer to thin vertical artifacts with a depth of 2–3 cm (Fig. 3). They are commonly found in healthy individuals (up to 80% of the population)⁽²⁰⁾. We observed them in 29 (93.5%) cases, mostly located near

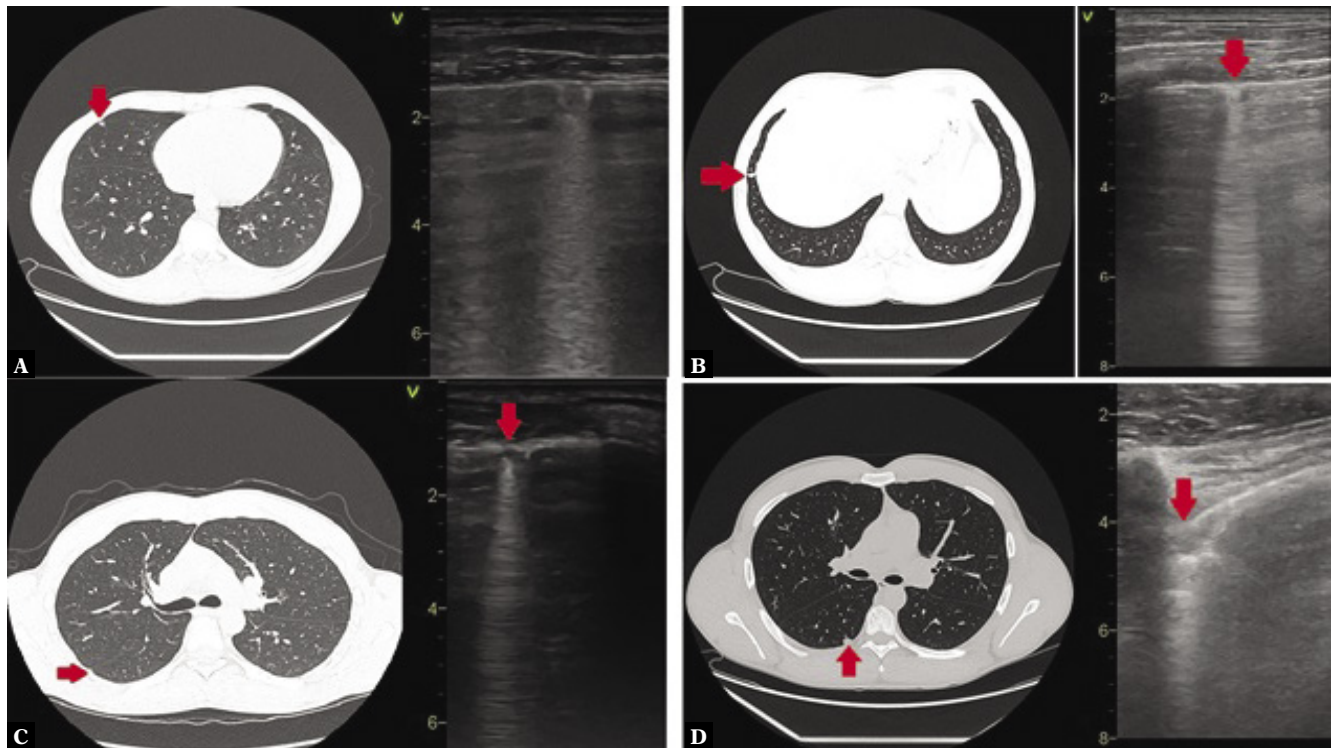


Fig. 4. The examples of the ultrasound view of consolidations. **A.** Subpleural annular post-inflammatory change with thick C-line, comparable to subpleural small consolidation. **B.** Small subpleural hyperechogenic change with thick C-line described then in HRCT as calcification. **C.** Small, hypoechogenic subpleural consolidation, comparable to the change visible then in HRCT. **D.** Paravertebral irregular consolidation, visible then in HRCT

a parenchymal organ (liver or spleen), sometimes their increased number helped finding consolidation. The areas with plural Z-lines were more prevalent in patients with more expressed symptoms, so high intensity of Z-lines was assessed as abnormal.

- Inflammatory consolidations with concomitant C-lines

Inflammatory consolidations were observed in 27 patients (87.1%). A total of 45 small subpleural changes (up to 4 mm) with accompanying thin C-line, and 25 larger subpleural changes (>4 mm) with hyperechogenic, thick 'comet tail'-like C-lines were found.

The ratio of consolidations per one patient was similar in all groups of different intensity of symptoms. A total of 33 (55.9%) zones with consolidations had a comparable view in CT. It is possible to extract the pattern of consolidations more comparable with CT images: from 24 zones with larger subpleural consolidations with thick, 'comet tail' C-line, 18 (75%) were confirmed by HRCT as inflammatory consolidations, calcifications or small nodules. (Fig. 4).

- Pleural line

After infection, thickening (>13 mm) and irregularity of the pleural line can be observed, and LUS seems to be a more accurate modality than HRCT (Fig. 5), but it needs to be emphasized that both have a limited specificity.

Detailed LUS findings are presented in Tab. 2.

HRCT

Abnormalities on HRCT were identified in 25 patients (80.6%), while in six cases totally normal lung parenchyma was revealed (19.4%).

Analyzing the 434 areas obtained, normal lung parenchyma had dominated in all groups but the percentage of normal parenchyma was slightly lower in the athlete with a severe course of SARS-Cov-2 (78.6%, Tab. 2). Both symptomatic and asymptomatic patients had abnormalities on HRCT. In 14 patients (45.2%), adhesions, small scarring or fibrotic changes were found. A total of 17 patients (54.8%) presented with small tumors, nodules or calcifications. In five patients (12.9%), more changes typically associated with COVID-19 (GGO, crazy-paving pattern and larger consolidations) were found.

Detailed HRCT findings are presented in Tab. 3.

LUS vs HRCT

The total sensitivity of LUS was 74.65%, while the specificity was 68.56%. The positive predictive value was 31.4%, while the negative predictive value was 93.2%.

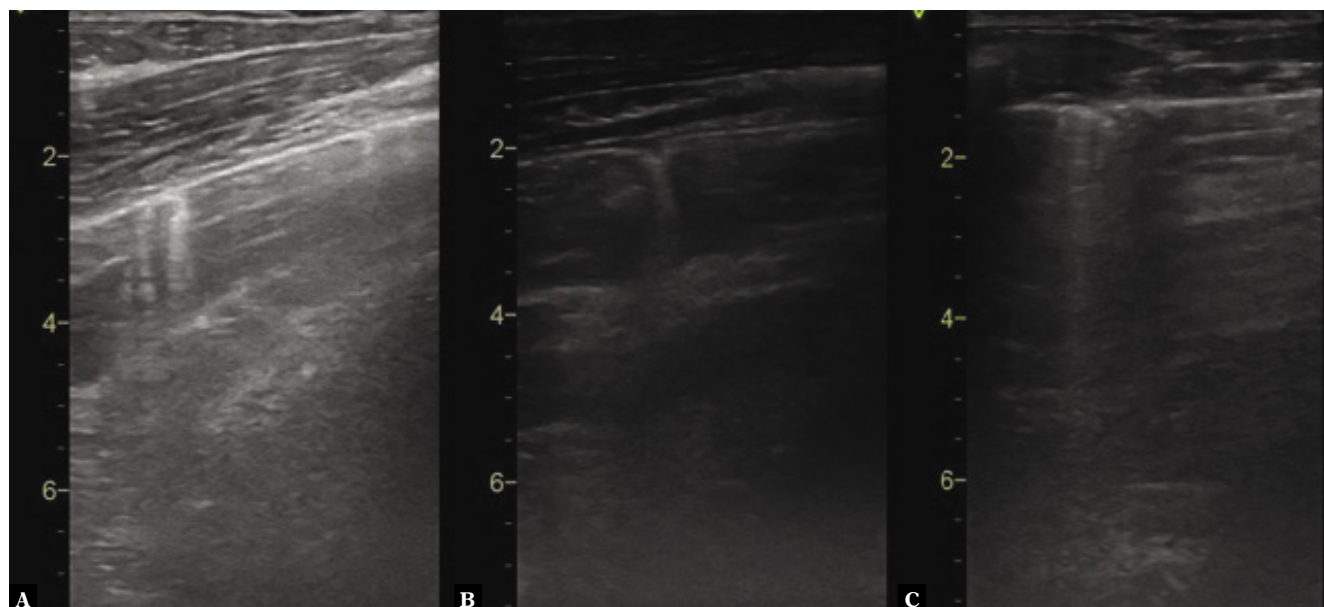


Fig. 5. Lung ultrasound patterns of the abnormal pleura line. **A.** Irregularity of the pleura due to presence post inflammatory change with accompanying Z-lines. **B.** Interrupted line of the pleura with concomitant Z-line. **C.** Irregularity of the pleura due to the presence of small fibrotic changes. In all figures, abnormalities coexist with a normal, A-line pattern- the phenomenon typical for COVID-19

The vast majority of ultrasound A-pattern areas (93.2%) corresponded to normal aeration of the lung parenchyma confirmed on HRCT. Only for 6.8% of A-line pattern areas the HRCT revealed an abnormal view. $N = 33$ (55.9%) of all areas with consolidations had equivalents in HRCT, but bigger consolidations with thick C-line corresponded with HRCT findings significantly better: 18 out of 24 areas (75.0%) had an abnormal HRCT image.

Discussion

The assessment of elite athletes after COVID-19 is typically focused on the cardiovascular system⁽¹³⁻¹⁶⁾. RTP protocols describe combined diagnostic paths with the use of various assessment methods: the most important include comprehensive history, physical examination, laboratory tests, ECG, echocardiography, Holter ECG, exertion tests, and CMR. The guidelines are focused on the diagnosis of long COVID-19 and myocarditis – a well-known risk factor for SCD. Only a few RTP pathways include a scheme for respiratory system assessment⁽¹³⁾. The doubts considered the necessity of extensive diagnostics because the course of infection is typically uncomplicated, and ARDS is only observed occasionally⁽¹²⁾.

The literature shows that a symptomatic course of SARS-Cov2 infection affects approximately two-thirds of infected athletes, while one-third of them are asymptomatic⁽¹²⁾. In our study, the lower frequency of the asymptomatic course (12.9%) might be a result of the willingness to undergo examination.

There are studies on the general population showing that pneumonia is found in 100% of patients with symptoms, and in up to 50% of asymptomatic individuals^(21,22). Based on these data, the assessment of lung function is desirable, including both imaging methods (CXR, CT) and functional tests (spirometry and CPET)^(18,19).

Both our study and other authors' observations^(20,23-25) have found no clear correlation between the intensity of symptoms in cases of mild COVID-19 and the radiological findings (CT scans).

We found changes in 80.6% of all CT scans, but the most characteristic pattern for COVID-19 (including GGO, crazy-paving pattern and consolidations) were observed in five patients (16.1%), both symptomatic and asymptomatic. Of note, three of them were evaluated shortly after the infection had resolved (11, 12 and 16 days

Tab. 3. Pattern of changes visible on HRCT

	Total	Asymptomatic (-)	Mild (+)	Moderate (++)	Severe (+++)
Number of patients (N)	31	4	17	9	1
Number of assessed slices (N × 14)	434	56	238	126	14
Normal parenchyma	363 (83.6%)	49 (87.5%)	200 (84.0%)	103 (81.7%)	11 (78.6%)
Minor changes (adhesions, small scars and fibrotic changes, small consolidations)	38 (8.6%)	2 (3.6%)	19 (4.3%)	15 (11.9%)	2 (14.3%)
Major changes (ground glass opacifications, big consolidations)	10 (2.3%)	3 (5.4%)	2 (0.8%)	3 (2.4%)	2 (14.3%)
Non-specific changes (nodules, small tumors)	25 (5.8%)	3 (5.4%)	15 (7.6%)	6 (4.8%)	1 (7.1%)

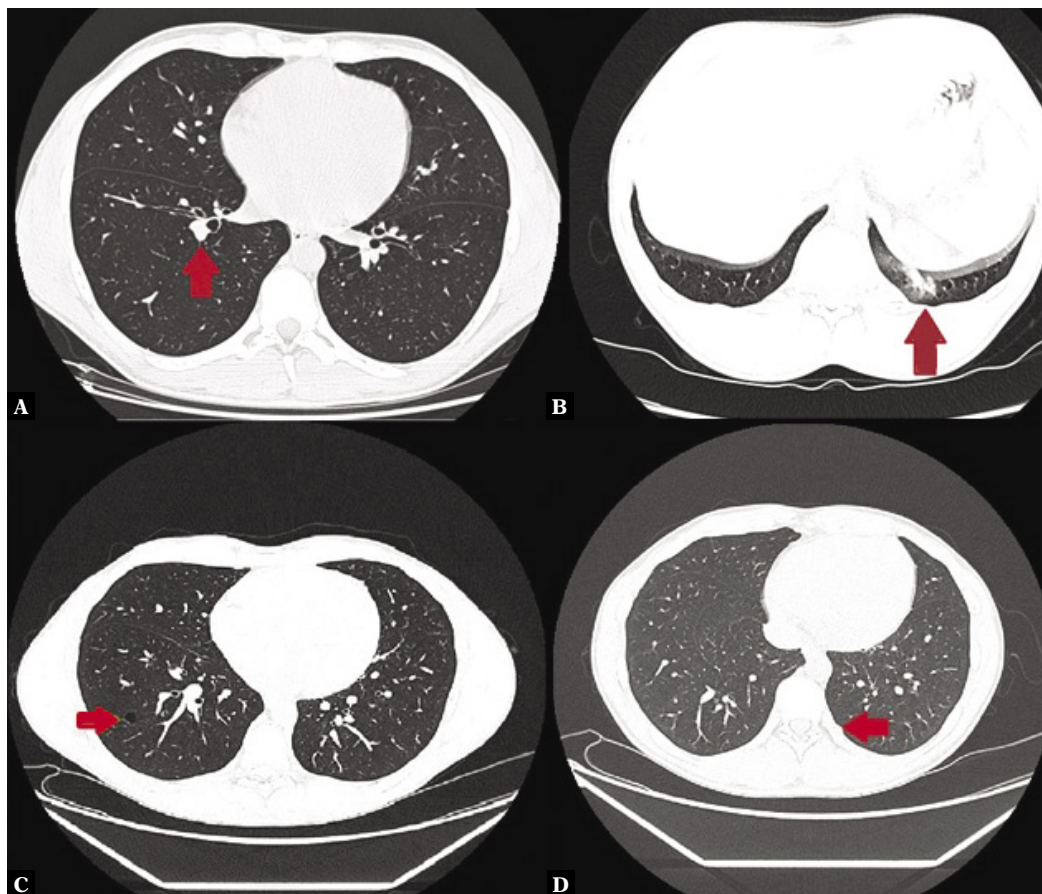


Fig. 6. The abnormalities not available for lung ultrasonography, visible in high resolution computed tomography. **A.** Peri-hilar small tumor. **B.** Consolidation near the base of the lung, close to spleen, with poor connection with the pleura line **C.** Small air cyst within the normal aerated lung parenchyma, **D.** Para-costal and para-vertebral small subpleural change

after positive PCR test), and one person with GGO had a severe course of infection – even though the assessment was performed on the 38th day after a positive PCR test, the changes were still visible. The abnormalities did not exceed 20% of lung involvement in any of the cases studied.

Even though LUS performed in patients with active COVID-19 has a well-established position in the literature⁽²⁶⁻³¹⁾; the higher LUS sensitivity in comparison to CXR⁽⁶⁾ and its high negative predictive value due to the changes characteristic for COVID-19⁽¹⁰⁾, its suitability for post-COVID-19 assessment is still unclear⁽²⁹⁾.

Our experience shows that a specific pattern of changes, determining further diagnostic steps, can be extracted and it comprises B-line pattern (but it was not revealed in this group of patients), consolidations with thick comet-tail C-line or low number of 'clear' A-line areas.

High (93.2%) compatibility of the ultrasound A-line pattern with normal lung parenchyma on HRCT must be highlighted (high negative predictive value in the study). On these grounds, it may be concluded that in patients with dominant A-line pattern HRCT is not obligatory,

which can help to avoid unnecessary radiation. This management can contribute to reducing costs, logistic barriers, and the time before resuming competitive activity.

Limitations of the study

The most important limitations include the retrospective character of the study, various time intervals from infection to assessment, and a lack of comparative examination before and during active infection. The number of cases was too small to perform an analysis with adequate statistical power. The use of LUS vs. HRCT was not compared in athletes with moderate/severe course of the disease, who were not analyzed in the study, and therefore the results cannot be extrapolated to that group. However, the majority of athletes had a benign course of COVID-19.

Other limitations concern the possibility of using ultrasound as a diagnostic method and include:

- no condition to find paracostal or paravertebral changes and perihilar abnormalities;
- no possibility to reveal changes if there is a poor connection with the pleura and in the case of proximity to tissue organ (Fig. 6).

Conclusions

Elite athletes have a low risk of severe course of the COVID-19. Lung changes after the infection are frequent, but not severe and not correlated with the severity of symptoms. The A-line pattern visible on LUS corresponded with normal lung parenchyma revealed on HRCT, and the percentage of ultrasound A-line pattern was decreasing with the severity of symptoms.

In view of its high negative predictive value, LUS might be implemented in the RTP protocols after COVID-19, especially in uncomplicated cases, in which HRCT seems to be too extensive.

Conflict of interest

This research received no external funding. Authors state no conflict of interest.

Author contributions

Original concept of study: MMB-O, MKon. Writing of manuscript: MMB-O, MKon. Analysis and interpretation of data: MMB-O, MKon. Final acceptance of manuscript: WB, MKuch. Collection, recording and/or compilation of data: MMB-O, MKon, AJ, WK. Critical review of manuscript: AJ, WK.

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