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Clinical use of densitometric analysis of lung pathology and digital data processing programs for determining surgical tactics in phthisiosurgical patients with HIV status

Objective — to determine the possibilities of using densitometric indicators of computed tomography (CT) and digital software processing of CT data in lung pathology for the formulation of personalized treatment tactics for phthisiosurgical patients with concomitant HIV pathology, and to justify the indications for surgical treatment.

Materials and methods. A retrospective analysis was conducted on the results of the examination and treatment of 11 patients with specific tuberculous lesions of the lungs. Specific therapy was initiated 2—3 months after the initial visit to the medical institution, and immunochromatographic tests for HIV and hepatitis, which were performed in advance, yielded doubtful (questionable) or negative results.

Patients underwent a general clinical examination, echocardiogram, fibrobronchoscopy with examination of bronchoalveolar lavage for Mycobacterium tuberculosis, and molecular genetic tests of sputum or bronchoalveolar lavage. Express tests for HIV, hepatitis B, and hepatitis C, as well as routine blood and urine tests, were carried out. The Aquilion TSX-101A Toshiba (Japan) tomography was used as the main research tool. Densitometric analysis of lung parenchyma was performed using DICOM-VIEWER PHILIPS in the areas of interest. Digital analysis of images obtained from CT slices was conducted using the Dragonfly program.

Results and discussions. The clinical manifestation of patients' «radiological findings» was asymptomatic in 81.8 % of cases and mostly perceived as a «post COVID-19 syndrome». The analysis of the laboratory data did not indicate specific signs of the disease in 72.7 % of cases. The study of the verified focal lesions without signs of destruction of the lung parenchyma during densitometric analysis of CT revealed densities that characterize exudative processes in the lung parenchyma (0—15 HU), which is a characteristic sign of a specific inflammatory process in the context of HIV infection. Histologically, high activity of a specific inflammatory process was detected in operated patients. During digital software processing, we observed a shift in densitometric indicators that are characteristic of the exudative phase of inflammation. Situations of HIV-associated infection and alteration-exudative reactions were noted, which were 100 % determined by densitometric analysis and digital software processing of the chest CT scan. Six patients underwent surgery on (2 lobectomies, 1 combined resection and 3 sublobar resections). Among the non-operated patients, 3 experienced a recurrence of a specific inflammatory process, and 1 patient still exhibits significant morphological changes in the parenchyma.

Conclusions. Densitometric analysis and digital software processing of CT scan allows you to objectify the patient's condition and reasonably prescribe personalized therapy. Identified patients with X-ray lesions of the lungs require a mandatory consultation with a thoracic surgeon and consideration of the issue of surgical treatment within 2—3 months after the start of specific therapy.

According to the WHO, annually more than 10 million people get tuberculosis [4]. The COVID-19 pandemic mostly led to a significant reduction in TB testing, but contributed to an increase in X-ray examinations. Difficulties in the functioning of the health care system caused by the COVID-19 pandemic led to a significant decrease in the number of people diagnosed with tuberculosis. As a result, there is an increase in a tuberculosis mortality [2]. Quite often, patients with established HIV and undetermined HIV status sought medical help. The tactics of treatment for this category of patients cause polemical debates up to this day. Morphological features of the course of the specific inflammatory process in HIV-infected patients are known, and they significantly affect the clinical manifestations of the disease [1, 2, 13].

Modern trends in the detection of tuberculosis lesions by questionnaires, as well as the use of diagnostic test, are definitely effective in a significant number of cases, but do not fully allow to solve clinical tasks. In a significant number of observations, the optimal and most effective measure is a combination of specific therapy with surgical treatment methods [10, 14, 18, 20].

Despite global trends towards the universalization of the diagnostic and treatment process for both tuberculosis and HIV, and the combination of these diseases, significant challenges remain for health care institutions [10].

In the context of resource constraints caused by the COVID-19 pandemic, which has been observed since 2019, and the social and demographic changes that have arisen in 2022, universal funds are not always available in full. On the other hand, the other hand, the relevance of the problems of differential diagnosis of generally accepted diagnostic procedures remains. Thus, radiological examination has a significant impact on the medical and diagnostic process, both as a screening, associated with the standard radiological methods and with the high-tech differential diagnostic tools, if we are talking about advanced and promising developments at the intersection of obtaining high-resolution radiological images and processing the obtained results with the use of modern information technologies. Mobile applications, decision support programs and other digital technologies that have entered our lives are becoming more and more widespread [6].

CT scan allows non-invasively and objectively assessing pathological changes in the lung parenchyma, using densitometry, both at the tertiary stage of providing care by specialists of a narrow profile and primary care doctors, when forming a patient treatment program [11]. Digital image analysis has confidently entered into a clinical practice over the last decade and is used in specialized treatment centers [9]. CT scan — is an image processing, with the involvement of various tools and ways, has been widely used in general medical diagnostics, particularly in oncology, and in the detection of tuberculosis recently [17, 19]. The use of intelligent CT scan evaluation systems, based on convolutional neural networks or artificial intelligence, is actively being implemented in everyday practice, significantly speeding up the diagnostic and treatment process, allowing to objectify and substantiate decision-making [12, 19].

Objective — to determine the possibilities of using densitometric indicators of CT scan and digital software processing of CT data to form personalized treatment tactics phthisiosurgical patients with concomitant HIV pathology and justify of indications for surgical treatment.

Materials and methods

A retrospective analysis of the results of the examination and treatment of 11 patients with specific tuberculous lesions of the lungs were carried out. Specific therapy and examination was started 2—3 months after the initial visit to the medical institution. Of the studied patients, 3 men and 8 women were observed. The age of the patients ranged from 30 to 55 years. The mmunchromotographic tests for HIV and hepatitis, which were made in advance, were doubtful (questionable) or negative. During hospitalization, patients underwent a general clinical examination, echocardiography, fibrobronchoscopy with examination of bronchial lavage for mycobacterium tuberculosis, molecular genetic tests of sputum or bronchial lavage. Express tests for HIV, hepatitis B and hepatitis C, routine blood and urine tests were carried out. Chest CT scan studies were performed on the Aquilion TSX-101A Toshiba (Japan) tomograph with densitometric analysis of the lung parenchyma DICOM-VIEWER PHILIPS. The Dragonfly program, provided free of charge by OBYECT RESEARCH SYSTEMS (ORS), Montreal, Canada, was used to study CT slices, enabling digital software image processing of the received data, segmentation, mathematical and statistical analysis of images, and construction of normal and segmented histograms. The results of identical clinical-diagnostic examinations were analyzed when patients repeatedly sought medical help.

Retrospective screening of hospitalized patients is available for analysis according to identical parameters, which was carried out using the electronic medical system MCMEDScientific, which operates at the Institute. The frequency of such patients seeking medical help is 10—11 % of the total number of treated individuals.

Table 1. **Clinical symptoms of patients with HIV status at initial visit**

Symptoms	Quantity	Percentage
No complaints	10	90.9
Dry cough	1	9.09
Discharge of sputum	0	0
An increase in body temperature	0	00
Dyspnea	2	18.1
Night sweats	2	18.1
Weakness	1	9.09
Hemoptysis	0	0
Appetite disorder	0	0
Fatigue	2	18.1

Table 2. **Laboratory symptoms of patients with HIV status at initial visit**

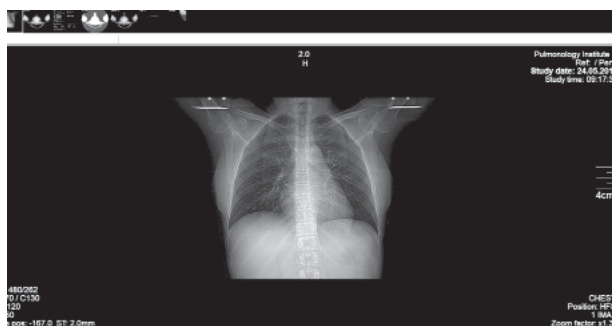| Symptoms	Quantity	Percentage
Doubtful HIV rapid test	4	36.3
Leukocytosis	3	27.2
Thrombocytopenia	4	36.3
Positive hepatitis B or hepatitis C express test	2	18.1
Mucobacterium tuberculosis in bronchoalveolar lavage waters	0	0
GenExpert	0	0

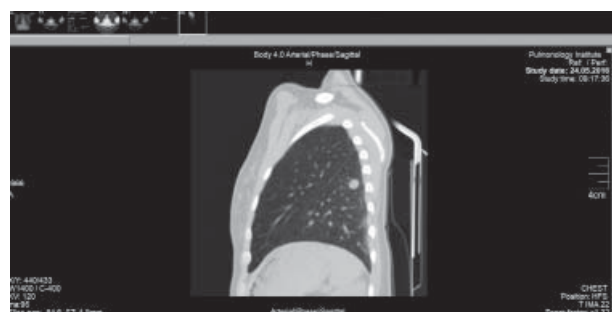Fig. 1. **X-ray of the patient at the initial request for help, direct projection**

Fig. 2. **X-ray of the patient at the initial request for help, lateral projection**

Taking into account the confirmed diagnosis when the patients were referred to the medical institution again, and the identical diagnostic set of examinations was carried out in the future, densitometric analysis of CT scan indicators and digital analysis of chest CT scan images were used for 5 patients.

Results and discussions

The data of the general clinical examination are presented in Table 1.

We did not observe clinical manifestations of lung diseases. Quite often, an asymptomatic picture and X-ray changes were considered at the primary care level as a «post COVID-19 syndrome». Three patients had symptoms of intoxication (27.3 %). Shortness of breath bothered 2 patients, 1 patient noted a dry cough. 81.8 % had an asymptomatic disease pattern.

Patients applied to the Institute with practically no complaints. Mostly, the appeal was aimed at clarifying the radiological changes detected during the radiological examination.

The generally accepted analysis of laboratory data did not indicate specific signs of the disease (Table 2). Much more informative was the analysis of the Echocardiogram when patients first visited the Institute, in which 36.3 % showed changes — increased pressure in the pulmonary artery.

X-ray changes that led to seeking help had characteristic features (Fig. 1 and 2). Verified focal lesions without signs of destruction of the lung parenchyma.

A study of the primary analysis of the hospitalized patients' CT in the visual mode confirmed the absence of destruction of the lung parenchyma. Densitometric analysis of the typical focus of the affected lung parenchyma proved the high activity of the specific tubercular inflammatory process in the lung parenchyma, which is characterized by density indicators of −8 HU (Fig. 3) [8].

The next stage was a digital software processing of CT slices, during which indicators in the zones of interest (ROI), segmentation and histograms of changed areas of the lung parenchyma were studied.

According to our data, the ROI areas were dominated by a density close to zero, which characterizes exudative processes in the lung parenchyma, characteristic of a specific inflammatory process against the background of HIV infection. The histological analysis of the patients' resected material showed a high activity of the specific inflammatory process in the studied areas. Fig. 4 and 5 present a normal histogram and a segmentation histogram of a patient with high activity of a specific tuberculous inflammatory process in the lung parenchyma, which

are characteristic of morphological changes of patients with a HIV status.

Digital software image processing makes it possible to reliably detect density shifts characteristic for the formation of a specific morphological understanding of a tuberculous lesion. It should be noted that the predominance of density indicators tending to zero is typical for HIV status. An example of a typical histogram of a morphological picture formation of a lung parenchyma lesion with HIV association (Fig. 6) and the formation of a specific lesion without concomitant HIV status (Fig. 7) are given below.

Segmentation histograms (Fig. 8 and 9) make it possible to precisely study the morphological features of pathological processes observed in the lung parenchyma in case of tubercular lesions, and make it possible to form assessment algorithms that become the basis for the development of intelligent networks and assessment systems [12].

Generally, HIV-associated tuberculosis was distinguished by an atypical clinical and morphological situation. HIV-associated infection cases were noted by an alteration-exudative reactions, which were 100 % determined by densitometric analysis or digital software processing of the chest CT scan images.
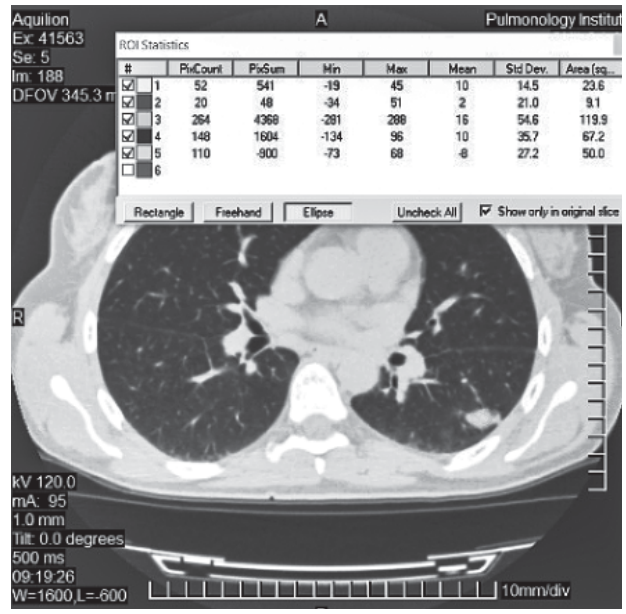

Fig. 3. **Densitometric analysis of the typical focus of the affected lung parenchyma with a high activity of a specific inflammatory process (– 8 HU)**

As in most similar observations, we have noticed generalization and dissemination of the process in the lung parenchyma, which is one of the manifestations of HIV-associated pulmonary tuberculosis [14, 17].
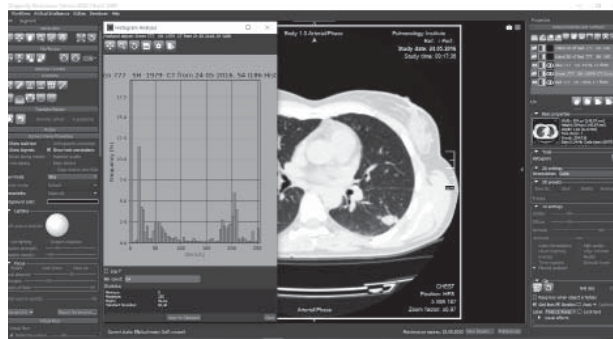

Fig. 4. **Histogram of a patient with high activity of a specific tuberculous inflammatory process in the lung parenchyma, characteristic of the formation of morphological changes concomitant with a HIV status**
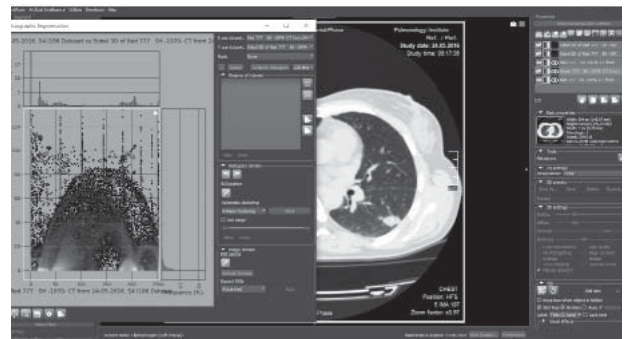

Fig. 5. **Segmentation histogram of a patient with high activity of a specific tuberculous inflammatory process in the lung parenchyma, characteristic of the formation of morphological changes concomitant with a HIV status**
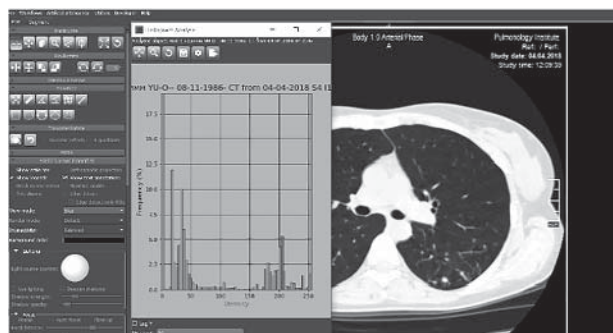

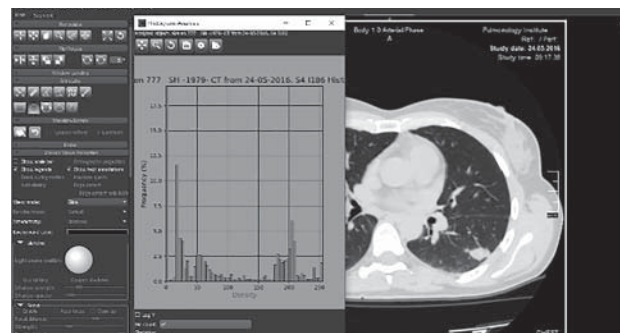Fig. 6. **Histogram of lung parenchyma of a patient with HIV status, with characteristic density indicators**

Fig. 7. **Histogram of lung parenchyma of a patient without HIV status, with typical density indicators**
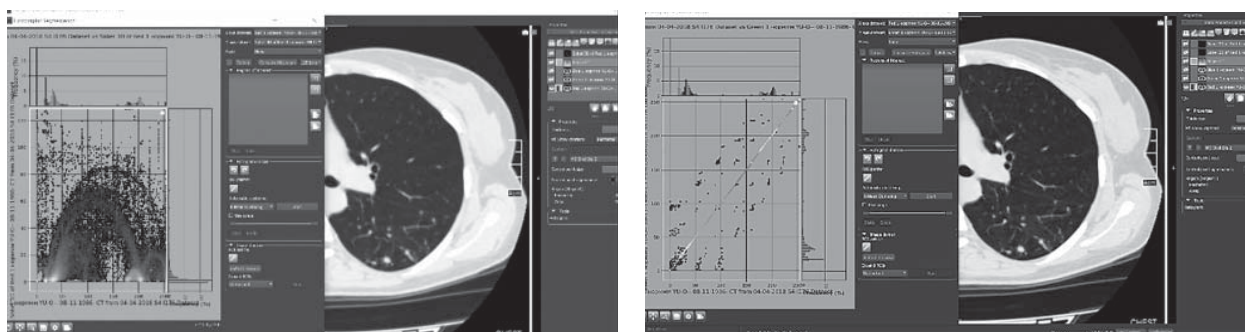
Fig. 8. **Segmentation histogram of lung parenchyma of a patient with HIV status, with characteristic density indicators**
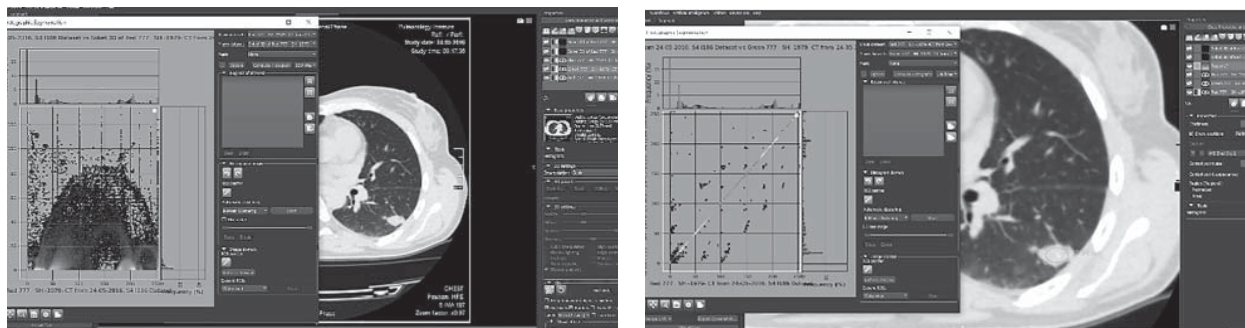

Fig. 9. **Segmentation histogram of the lung parenchyma of a patient without HIV status, with typical density indicators**

Usually, the repeated appeal of patients was prompted by the deterioration of the condition and the upgrowth of clinical symptoms. During the re-examination, the clinical symptoms were more expressive. Hyperthermia was a characteristic feature, which was observed in 63.6 % and weakness, which was found in 54.5 % of cases. The upgrowth of the clinical view was marked by the manifestation of the intoxication syndrome (data are presented in Table 3).

Two patients developed hemoptysis, prompting urgent hospitalization. Sputum was observed in 45.4 % of cases. A specialized study made it possible to establish a specific tuberculous inflammatory process. The data are presented in Table 4.

Retrospectively evaluating the identified features of the clinical case, we observe the need for additional examination of such kind of patients: conducting a PCR study to determine the viral load and research by the immunoblotting method, without forming a personalized therapy based on immunochromatographic tests.

After all, it is known that productive inflammation, particularly the granulomatous process, is characterized by the infiltration of mononuclear cells and lymphocytes with the proliferation of fibroblasts. Fibrosis and destruction of the parenchyma are easily distinguished both by automated complexes in the analysis of CT scan images and in the densitometric chest CT scan analysis [3, 5, 15].

We would like to make a note that patients with a satisfactory result of conservative therapy were

Table 3. **Clinical symptoms of patients with HIV status when referred after 2—3 months**

Symptoms	Quantity	Percentage
No complaints	0	0
Dry cough	1	9.09
Discharge of sputum	5	45.4
An increase in body temperature	7	63.6
Dyspnea	4	36.3
Night sweats	7	63.6
Weakness	6	54.5
Hemoptysis	2	18.1
Appetite disorder	3	27.2
Fatigue	4	36.36

Table 4. **Laboratory findings of patients with HIV status when seeking medical help after 2—3 months**

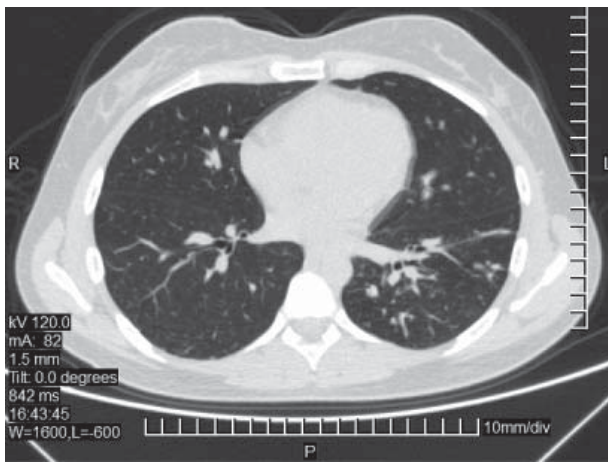| Symptoms	Quality	Percentage
Positive HIV rapid test	5	45.4
Leukocytosis	3	27.2
Thrombocytopenia	7	63.6
Positive express test for hepatitis B or hepatitis C	2	18.1
Mucobacterium tuberculosis in bronchoalveolar lavage waters	4	36.3
GenExpert	4	36.3

Fig. 10. Chest CT scan of a patient with HIV status after 2 years of treatment. The appearance of focus and infiltrates in both lungs with a relapse of the tubercular process is noted
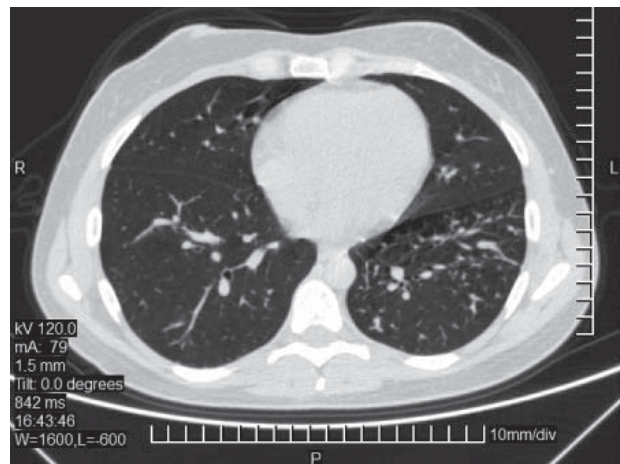

Fig. 11. Chest CT scan of a patient with a HIV status after 2.5 years of treatment. The bullous changes in the parenchyma and focus of a specific tubercular process is noted

not included in the study. Six of 11 patients underwent surgical treatment (54.5 %) with satisfactory results. Two lobectomies, one combined resection and 3 sublobar resections were performed. The postoperative period was without any complications. In one case, a prolonged discharge of air was noted. The treatment was carried out according to the phthisiologist's recommendation. Patients are observed for 3 years, noting the positive result of the received treatment.

Five patients refused surgical treatment. Two patients completed the treatment with a full positive clinical and radiological effect. At two-year follow-up, one case was interesting to be observed by the increase of final major changes in the lung parenchyma, and tuberculosis relapsed in two other cases (Fig. 10—12).

We emphasize that among the major final changes, our patients had focuses with a low density of lung parenchyma, which significantly increase the probability of recurrence of the disease. In these cases, the use of surgical treatment tactics significantly reduces the risk of recurrence of the tuberculosis process and increases the overall effectiveness of treatment [1, 18].

In this way, the use of densitometric analysis of chest CT scan and digital software image processing of chest CT scan provided the basis for an in-depth additional examination of patients, which made it possible to establish a specific lesion of the lung parenchyma, to start anti-tuberculosis therapy and ART therapy. With the help of specific therapy and ART therapy we could have a possibility to ensure the cure of patients with minimal residual changes in the lung parenchyma, reducing the duration of treatment by 2—3 months.

Fig. 12. Chest CT scan of a patient with HIV status after 1.8 years of treatment. The appearance of final major changes in the lung parenchyma with relapse of the tubercular process are noticed

Conclusions

CT-densitometry allows you to objectify the patient's condition and reasonably prescribe personalized therapy of phthisiosurgical patients, as opposed to the still widely used subjective justifications.

According to the data we received, concomitant HIV infection hides the clinical signs of specific inflammation, which requires an in-depth examination in the conditions of a specialized institution and carrying out ELISA analysis and determining the viral load in difficult diagnostic cases.

Radiologically detected lung lesions require a mandatory consultation with a thoracic surgeon and consideration of the issue of surgical treatment within 2—3 months after the start of specific therapy.

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Клінічне використання денситометричного аналізу патології легень та цифрової програмної обробки даних для визначення хірургічної тактики у фтизіохірургічних пацієнтів з ВІЛ-статусом

Мета роботи — визначити можливості застосування денситометричних показників комп'ютерної томографії (КТ) та цифрової програмної обробки даних КТ патології легень для персоніфікованої лікувальної тактики фтизіохірургічних хворих при супутній ВІЛ-патології та обґрунтування показань до хірургічного лікування.

Матеріали та методи. Проведено ретроспективний аналіз результатів обстеження та лікування 11 пацієнтів зі специфічним туберкульозним ураженням легень. Специфічна терапія розпочата через 2—3 міс після первинного звернення в медичний заклад. Результати імунохроматографічних тестів

на вірус імунодефіциту людини (ВІЛ) і вірус гепатиту були сумнівні або негативні. Пацієнтам виконували загальноклінічне обстеження, ехокардіографію, фібробронхоскопію з дослідженням промивних вод бронхів на наявність мікобактерії туберкульозу, молекулярно-генетичні тести харкотиння або промивних вод бронхів. Проводили експрес-тести на ВІЛ, гепатит В і С, рутинні дослідження крові та сечі. Дослідження виконували на томографі Aquilion TSX-101A Toshiba (Японія). Денситометричний аналіз легеневої паренхіми проводили за допомогою DICOM-VIEWER PHILIPS у ділянках інтересу (ROI), цифровий аналіз зображень отриманих для дослідження зрізів КТ — за допомогою програми Dragonfly.

Результати та обговорення. Клінічна маніфестація у пацієнтів із рентгенологічними «знахідками» у 81,8 % випадків була безсимптомною і сприймалася здебільшого як «постковідний синдром». Аналіз лабораторних даних не виявив специфічних ознак захворювання у 72,7 % випадків. Верифіковані вогнищеві ураження без ознак деструкції легеневої паренхіми при аналізі денситометричних показників КТ виявлялися величинами щільності, які свідчать про наявність ексудативних процесів у паренхімі легені (0—15 HU), що є характерною ознакою специфічного запального процесу на тлі ВІЛ-ураження. Гістологічно у прооперованих пацієнтів виявлено високу активність специфічного запального процесу. При цифровій програмній обробці зафіксовано характерний для ексудативної фази запалення зсув денситометричних показників. За наявності ВІЛ-асоційованої інфекції виявлено альтераційно-ексудативні реакції, які в усіх випадках визначалися при денситометричному аналізі та цифровій програмній обробці зображень КТ органів грудної клітки. Прооперовано 6 пацієнтів (2 лобектомії, 1 комбінована резекція та 3 сублобарні резекції). Серед неоперованих пацієнтів у 3 виник рецидив специфічного запального процесу, в 1 пацієнтки зберігаються значні морфологічні зміни в паренхімі.

Висновки. Денситометричний аналіз та цифрова програмна обробка зображень КТ дає змогу об'єктивізувати стан пацієнта та обґрунтовано призначити персоніфіковану терапію фтизіохірургічним хворим. Виявлені хворі з рентгенологічним ураженням легень потребують обов'язкової консультації торакального хірурга та розгляду питання про оперативне лікування протягом 2—3 міс після початку специфічної терапії.

Ключові слова: туберкульоз, денситометрія, цифрова програмна обробка зображень, хірургічне лікування, ВІЛ-інфекція.

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