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Thermal topography of metastatic lymph nodes and lymphomas during radiotherapy

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Monitoring of disease dynamics and treatment efficiency is important application of thermal infrared (IR) imaging in medicine [2]. Due to non-invasive, patient-friendly and cost-effective approach, thermal examination can be carried out as often as necessary over patient treatment. The IR imaging is a remote method of functional analysis. The additional but very significant clinical information, inaccessible to other medical methods of visualization, can be received from patient's external temperature distribution. In this case, pathophysiological-based understanding of thermograms (thermal IR images) is necessary for informative interpretation of the monitoring results.

Purpose – to present the results of the measurement of thermal parameters of human skin surface in the projection of lymphomas and metastatic lymph nodes (LN) in patients treated with radiotherapy (RT).

Material and methods

Gamma-therapeutic devices Rokus-M and Theratron Elite-80 were used for RT in accordance with the standard course of fractionation: 4 five-day cycles of daily exposure (2-day weekend - without irradiation), daily dose (DD) » (2÷3) Gy, the total dose (TD) » 40 Gy. Eight patients (4 – with lymphomas and 4 – with metastatic lesions of LN) were examined by thermal IR imaging system prior to treatment start and weekly during RT (5 IR sessions).

The grade of oral mucositis (OM) and dermatitis (D) caused by radiation for patients with head/neck cancer, and the grade of D for patients with other tumor localization, were estimated visually on relevant clinical symptoms just before each IR-session. In accordance with standard scale [6], the OM and D grades were evaluated as integer values 0 ... 4, where OM (0) and D (0) correspond to complete absence of relevant symptoms, and OM (4) and M (4) indicate maximum damage of mucosa and skin (interruption of RT).

Thermal survey of patients was carried out with the thermal IR imaging system developed and produced in LTPE of NAS of Ukraine. The device based on uncooled 384 x 288 pixels focal-plane array features spectral range of 8–14 micrometers, temperature sensitivity of 0.06 ^{0}C, spatial resolution of 1 milliradian, and an original software package specialized for medical application [3].

The possibility of tumor detection by thermal IR imaging method was determined using the criterion of thermal symmetry [5] prior to treatment start (IR session #0). To quantify the changes in the intensity of thermal radiation from skin surface, the relative temperature scale (comparing to a reference temperature) was used. The area with the reference temperature was selected individually for each patient, taking into account the tumor localization. The reference area remained unchanged during subsequent monitoring of the particular patient.

Results and discussion

The thermograms of the head/neck of patient A (52 years) prior to treatment start are shown in Fig.1. Diagnosis: metastasis of cancer in conglomerate of right cervical LN from undiagnosed primary tumor ($T_xN_xM_1$). Histology: planocellular non-keratinizing cancer; the status: after polychemotherapy (PCT). The zone of irradiation (10x12) cm^2 is marked by a black rectangular on the thermogram; black spot - bandage after biopsy.

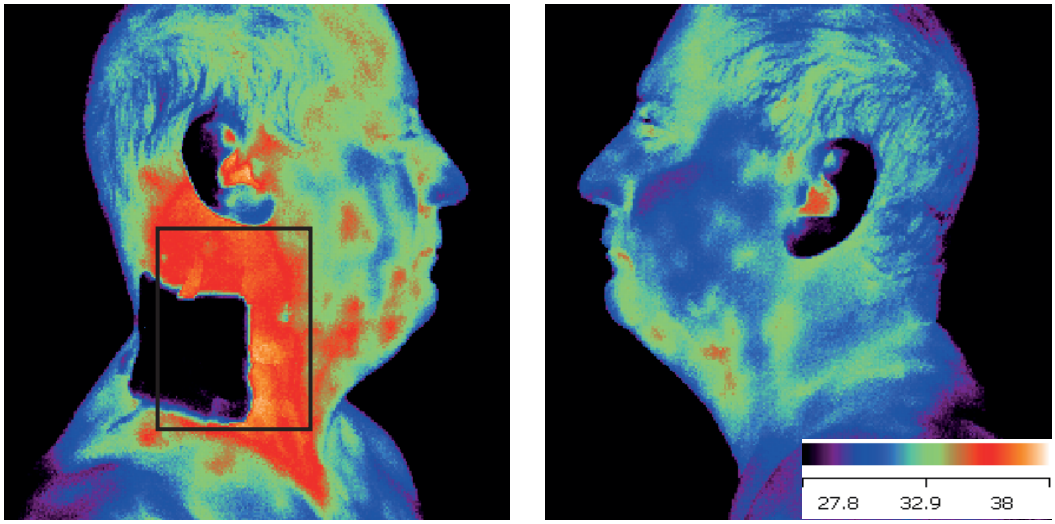

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Fig. 1. *Lateral thermograms of patient's head/neck prior to RT: the thermogram with thermal imprint on the skin of conglomerate of the right cervical LN with metastasis (A); the thermogram of the projection of the left intact LN (B).*

The dynamics of the anomalous thermal field on the skin taken during RT is illustrated in thermograms of patient A (Fig.2). The red regions correspond to a temperature equal to or higher than reference temperature (average temperature over the eyes' medial angle spot [1, 4]).

The lateral thermograms of patient A with marked areas of interest are shown on Fig 3

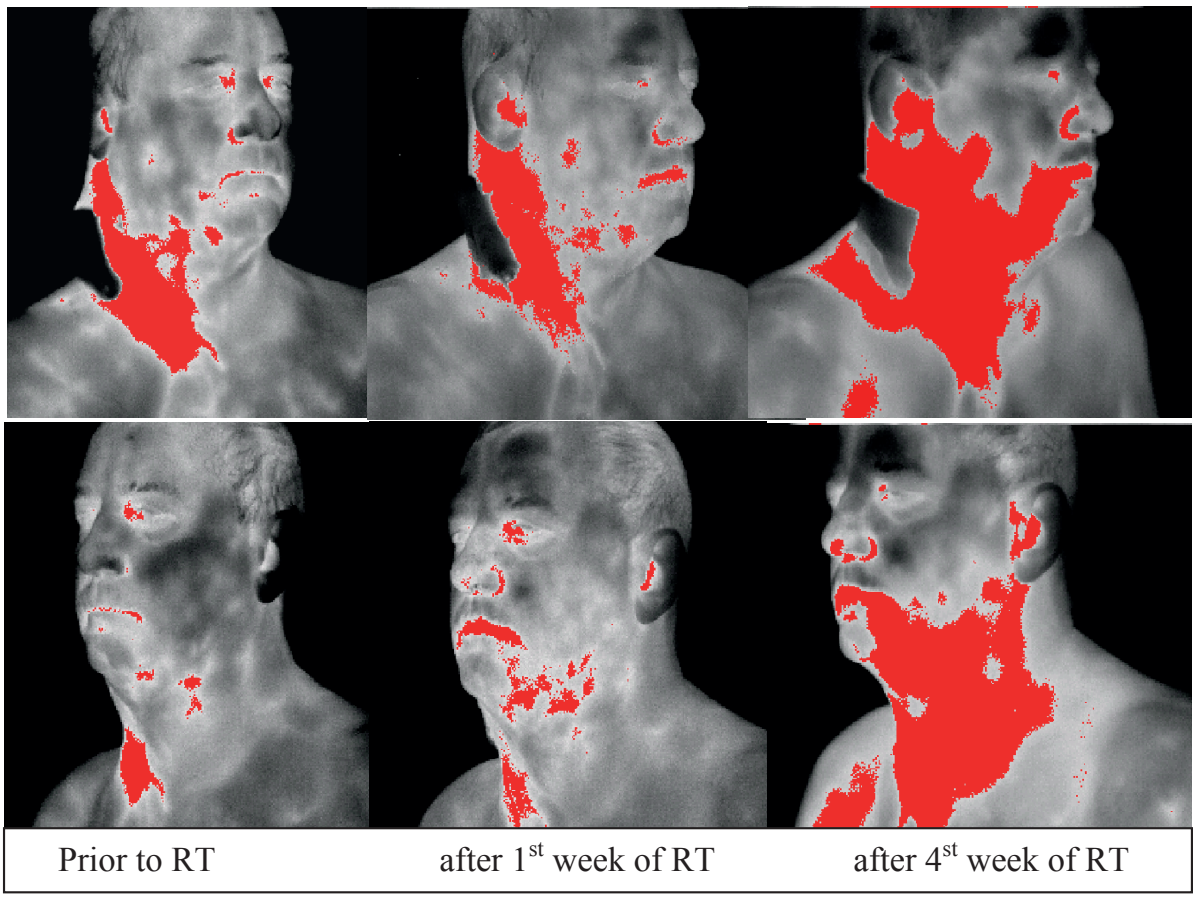

Fig. 2. *Dynamics during RT of anomalous thermal field in relative scale.*

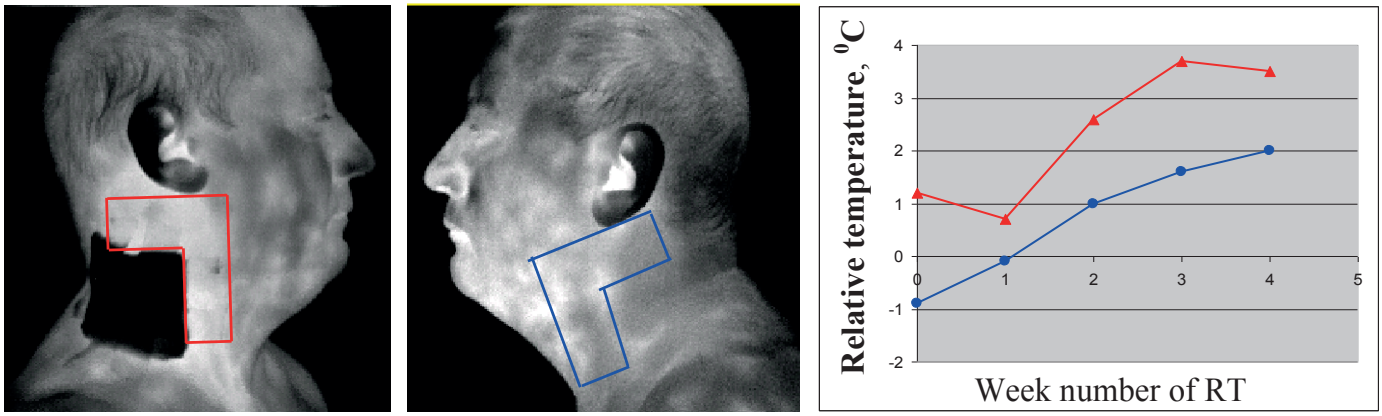

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Fig. 3. *Dynamics of patient A's skin surface temperature during RT: thermograms with marked areas of interest (A), the changes of average relative temperatures in areas of interest (B).*

(A). The area of interest in the projection of the amazed LN coincided with the zone of irradiation (minus the region of the bandage) is outlined on the image with red line; contralateral symmetrical area of interest in the projection of the intact LN is contoured with blue line on another lateral image.

The changes of the average relative temperature on the skin surface in each area of interest detected during RT are presented in Fig. 3 (B) with the curves of the corresponding color.

One can assume that blue curve reflects the development of OM, and the red curve reflects the superposition of changes in OM, D and own temperature of the amazed LN conglomerate. The behavior of the skin surface temperature, caused by the development of OM (blue curve) is typical for irradiated head/neck tumors (excess skin temperature caused by the development of D behaves similarly [1]). Contrariwise, the total skin temperature in projection of the amazed LN decreased at the initial stage of RT (first week of RT).

Comparing the changes in temperatures in symmetrical areas of interest and taking into account the dynamics of OM and D of patient A (see table), we can assume the presence of simultaneous processes: (i) decreasing of the internal temperature of the LN with metastasis thanks to the treatment (which reduces the temperature of its thermal imprint on the skin), and (ii) increasing of the skin temperature caused by mucositis and dermatitis. (In the table: *- residual mucositis caused by the prior PCT.)

Clinical examination of this patient after RT showed a small positive dynamics because of low radiosensitivity of the tumor and the vastness of lesion. Further treatment tactics is PCT.

Table.
Grade of OM and D of patient A during RT.

Toxic reaction grade	TIR session (week of RT) number				
	0 (prior to RT)	1	2	3	4
OM	1*	2	3	3	3
D	0	1	2	3	3

A similar behavior of anomalous thermal fields on the skin surface in projection of the tumor can be seen at lymphomas. The thermal image of inguinal area prior to RT start in patient B (52 years) with diagnosis: inguinal non-Hodgkin's MALT lymphoma in III-stage is shown on Fig.4 (A). The patient underwent a course of RT of right inguinal-femoral-iliac LN (DD » 2 Gy, TD » 36 Gy). The irradiation zone (20x20) см^2 coincides with area of interest (the black square on the image). Fig.4 (B) – thermal imprint of the lymphoma in details.

At this tumor localization, to quantify the temperature changes of the thermal imprint of lymphoma, the scale of relative temperatures is formed using the criterion of thermal symmetry. The difference between the average temperature of the area of interest (20x20) cm^2, and the temperature of equal symmetrical contralateral healthy region, was calculated for each IR session. In this case, there is a significant decrease in the relative temperature (» 2,5^0 C) during the first 2 weeks of RT, that can be explained by a decrease of the internal temperature and the volume of lymphoma. Then,

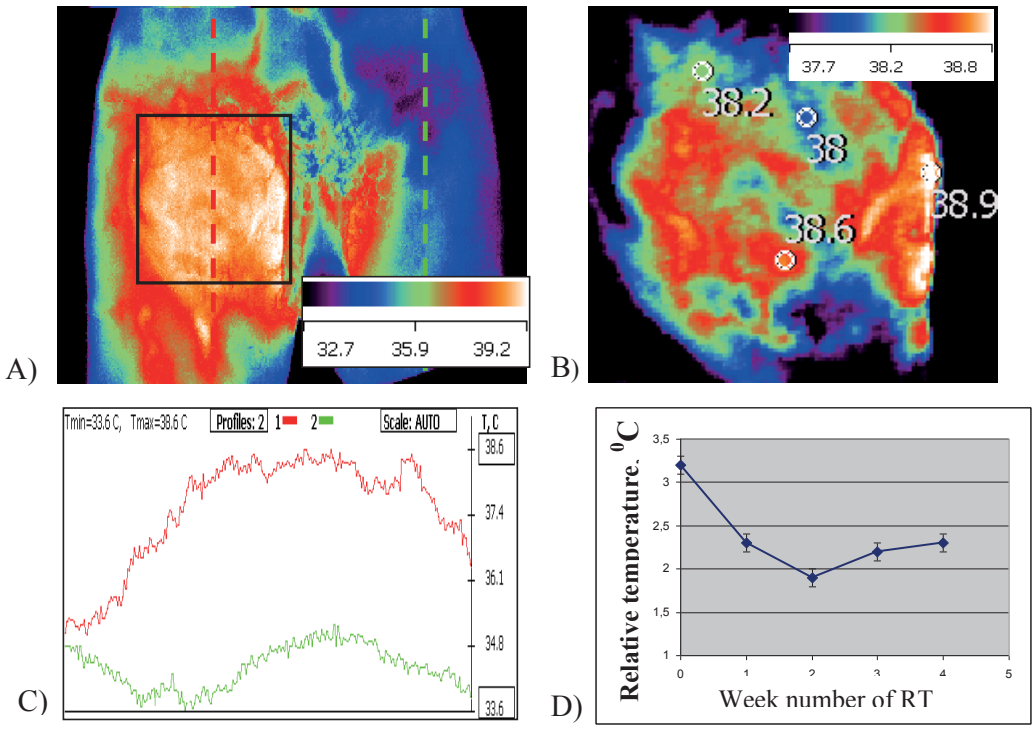

Fig. 4. *TIR study of the non-Hodgkin's MALT lymphoma during RT: the frontal thermogram of inguinal area prior to RT start with marked area of interest (A); an enlarged thermal imprint on the skin of lymphoma prior to RT start (B); the temperature along symmetrical lines running from top to bottom across the projection of lymphoma and healthy contralateral region (C); the changes of average relative temperature in area of interest (D).*

a slight increase in the relative temperature caused by mild dermatitis, occurs (» 0,5 ^{0}C). The grade of dermatitis from IR-session to session is: D (0, 1, 2, 2, 2). As a result of RT, the positive dynamics was noted: a partial regression of the tumor (from diameter 18 cm to 10 cm). The tactics of further treatment is PCT.

Fig 5 shows the change during RT of average relative temperature in the area of interest in projection of the right subclavian LN in patient C (37 years) with the diagnosis: medullary carcinoma of the right breast ($T_2N_1M_0$); the status - after the radical mastectomy. The postoperative course of RT was carried out to the armpit region: DD = 2 Gy, TD = 40 Gy, irradiated zone - (8x12) cm^2, and to the subclavian region: DD=2 Gy, TD= 42 Gy; irradiated zone - (9x12) cm^2. The temperature relative scale was formed by the criterion of ther-

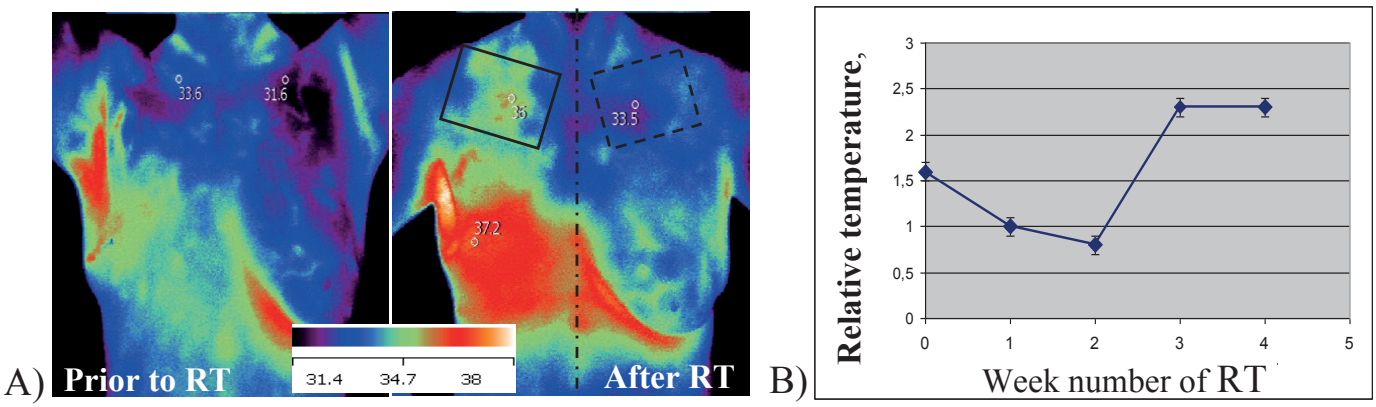

Fig. 5. *TIR study of subclavian LN: The thermograms of patient C prior to and after RT with a marked area of interest (A), the change of the average relative temperature in the area of interest during RT.*

mal symmetry. The thermograms prior to RT start and after RT finish with marked area of interest are shown in the Fig 5 (A). The dynamics of average relative temperature in the area of interest (subclavian region) is similar to the examples represented above (Fig 5 (B)).

Conclusion

As a result, decrease of the temperature of the skin surface in projection of tumor or injured LN at the first stage of RT (1…2 weeks) and the subsequent increasing of the temperature during the second half of the treatment was observed in 3 patients with lymphomas and in 4 patients with metastatic LN. Large B-cell non Hodgkin's lymphoma of palatine tonsil in 8-th patient of the group under study was not detected by thermal IR imaging method prior to RT start. In this case, the dynamics of the abnormal thermal field on the skin surface of patient's head/neck reflects only the development of OM and D caused by RT.

Thus, the presence of two simultaneous processes could be supposed. There are: (i) a decrease in the temperature of the skin surface in projection of tumor or metastatic LN due to decrease of their own temperature caused by destructive effect of RT; and (ii) increase in the skin surface temperature due to the local post-radiation hyperemia development.

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THERMAL TOPOGRAPHY OF METASTATIC LYMPH NODES AND LYMPHOMAS DURING RADIOTHERAPY

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Purpose – to resent preliminary results of the temperature mapping of the skin areas situated over the lymphomas and metastatic lymph nodes in patients treated with radiotherapy (RT).

Materials and methods. Eight patients with the lymphomas and metastatic lymph nodes have been studied by thermal infrared (IR) imaging method during the RT. The survey of patients was carried out with an IR imaging system based on uncooled 384 x 288 pixel focal-plane array. The IR system features the spectral range of 8–14 μm, the temperature sensitivity of 0.06 ^{0}C, the spatial resolution of 1 milliradian, and an original software package specialized for the medical application.

Conclusion. The results of the quantitative analysis of the thermograms can be explained by the presence of two simultaneous processes: (i) a decrease in the internal temperature of the tumor or metastatic LN caused by the destructive effect of RT; and (ii) an increase in the skin surface temperature due to the development of local toxic reactions (dermatitis and mucositis).

Keywords: Infrared imaging, radiotherapy, lymph node, lymphoma.

ТЕРМОТОПОГРАФІЯ МЕТАСТАТИЧНИХ УРАЖЕНИХ ЛІМФАТИЧНИХ ВУЗЛІВ І ЛІМФОМ ПРИ ПРОМЕНЕВІЙ ТЕРАПІЇ

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Мета – представити результати вимірювання параметрів аномальних теплових полів на шкіряному покриві в проекції лімфом та метастатичних уражених лімфатичних вузлів в процесі променевої терапії.

Матеріали та методи дослідження. Вісім пацієнтів з лімфомами і метастатичними ураженнями лімфовузлів були обстежені протягом курсу променевої терапії методом інфрачервоної термографії. Термографування пацієнтів здійснювалося інфрачервоним термографом на основі матриці, що не охолоджується, з (384x288) мікроболометричних приймачів з температурною чутливістю 0,06 ^{0}C і просторовою розподільною здатністю 1 мрад.

Висновки. Отримані результати кількісного аналізу термограм можна пояснити наявністю 2 паралельних процесів: (і) зменшенням внаслідок променевої терапії внутрішньої температури лімфоми або лімфовузлів, (іі) збільшенням температури шкіряного покриву внаслідок розвитку локальних променевих реакцій (дерматиту та мукозиту).

Ключові слова: інфрачервона термографія, променева терапія, лімфатичний вузол, лімфома.

ТЕРМОТОПОГРАФИЯ МЕТАСТАТИЧЕСКИ ПОРАЖЕННЫХ ЛИМФАТИЧЕСКИХ УЗЛОВ И ЛИМФОМ ПРИ ЛУЧЕВОЙ ТЕРАПИИ

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Цель – представить результаты измерения параметров аномальных тепловых полей на кожном покрове в проекции лимфом и метастатически пораженных лимфатических узлов в процессе лучевой терапии.

Материалы и методы исследования. Восемь пациентов с лимфомами и метастатически пораженными лимфоузлами были обследованы на протяжении курса радиотерапии методом инфракрасной термографии. Термографирование пациентов производилось инфракрасным термографом на основе неохлаждаемой матрицы (384x288) микроболометрических приемников с температурной чувствительностью 0,06 ^{0}C и пространственным разрешением 1 мрад.

Выводы. Полученные результаты количественного анализа термограмм можно объяснить наличием 2 параллельных процессов: (і) уменьшением вследствие ЛТ собственной температуры лимфомы или пораженных лимфоузлов, (іі) увеличением температуры кожного покрова вследствие развития локальных лучевых реакций (дерматита и мукозита).

Ключевые слова: инфракрасная термография, лучевая терапия, лимфатический узел, лимфома.

Патенти

СПОСІБ ПРОГНОЗУВАННЯ ДИНАМІКИ ВОГНИЩЕВИХ ЗМІН ПРИ ЛІКУВАННІ ХВОРИХ НА ТУБЕРКУЛЬОЗ ЛЕГЕНЬ

№ 107999; Мельник В.М.; Кужко М.М.; Линник М.І.; Процик Л.М.; Гульчук Н.М.

Спосіб прогнозування динаміки вогнищевих змін при лікуванні хворих на туберкульоз легень, що полягає у рентгенівському дослідженні органів грудної порожнини, який відрізняється тим, що проводять вихідне обстеження органів грудної порожнини за допомогою комп'ютерного томографа із записом результатів дослідження на цифровий носій та їх програмним опрацюванням, а саме: дослідження середнього значення щільності туберкульозного вогнища на заданій площі, і при середньому значенні щільності - 41,6±51,1 од. Хоунсфільда або нижче прогнозують розсмоктування вогнищ, а через 2 місяці лікування проводять контрольне обстеження, аналізують ідентичні аксіальні зрізи вихідного та контрольного обстежень та досліджують вогнища, які мали щільність 38,8±14,2 од. Хоунсфільда або вище при вихідному обстеженні, і при зниженні цього показника прогнозують розсмоктування вогнища, а при його збільшенні - кальцинацію.