

Repeated CT examinations, radiation dose and attributable cancer risk in patients with lymphoma

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Aims and objectives

Introduction

Lymphomas is a heterogeneous group of malignant tumors characterized by lymph nodes and extralymphatic organs involvement. There are more than 30 different morphological variants of lymphomas that combined into two large groups - Hodgkin Disease (HD) and Non-Hodgkin's Lymphomas (NHL). In a view of the systemic nature of disease, whole body CT scan is carried out before start of treatment for tumor staging [1]. Additionally, CT is used for intermediate control in the course of chemotherapy, for radiotherapy treatment planning, and to monitor patients after treatment.

It is well known that CT is a relatively high radiation dose diagnostic imaging modality [2]. In oncology CT is the most commonly used diagnostic technique and its contribution to the radiation exposure of the population increases. So, share of CT examinations in roentgenodiagnosics in Belarus in 2007 was 1.8% but 25% in N.N. Alexandrov National Cancer Center of Belarus (35049 CT examinations). In 2012 the proportion of CT examinations at our institution increased to 43% (43717 examinations).

Concerns about radiation doses in diagnostic imaging are associated, in particular, with stochastic effects of irradiation such as radiation-induced cancer and heritable effects. According to the International Commission on Radiological Protection (ICRP), there is no minimum threshold of radiation dose below which cancer induction is not possible (linear no-threshold concept). The risk of radiation- induced cancer is 1 in 20000 after irradiation at a dose of 10 mSv [3], which roughly corresponds to one CT scan of abdomen and pelvis. Irradiation of patients during medical X-ray diagnostic procedures can be the cause of 1-3 % of cancers [4].

The aim of our study was to determine the number, types and timing of CT examinations in patients with lymphoma, to estimate cumulative effective dose and attributable risk of cancer.

Methods and materials

50 patients with lymphoma (19 HD and 31 NHL, 25 males and 25 females, aged 18-83 y. o.) who were treated in our institution in 2010-2011 were included in this retrospective study. All patients completed treatment and entered follow-up by the time of analysis (November 2013). Average follow-up period was 9.1 months (range 0-31 month). CT examinations starting 4 months before start of treatment till the time of analysis were searched on radiology server. Cumulative effective dose per patient was calculated by multiplying number of exams by mean effective dose from national CT radiation doses survey per examination type: neck/thorax/abdomen/pelvis - 2.6/6.9/7.0/7.8 mSv [5]. Attributable risk of cancer was calculated using ICRP publication 103 coefficient $4.1 \times 10^{-2} \times \text{Sv}^{-1}$ [3].

Results

In HD an average of 5.7 cycles of chemotherapy were conducted per patient (range 2-12 cycles), in NHL - 7.9 cycles (range 4-18). Radiotherapy was applied in 15 (79%) patients with HD and 16 (52%) patients with NHL.

Total number of CT examinations performed in 50 patients was 665. It was performed 13.3 CT exams in average per patient. 32 (64%) patients underwent 10 or more CT exams, 10 (20%) patients underwent 20 or more exams. The biggest proportion of CT examinations was carried out during chemotherapy (244 exams, 37%), followed by examinations after treatment (198 exams, 30%), before treatment (169 exams, 25%) and for radiotherapy planning (54 exams, 8%). Distribution of CT studies by time period is presented in Table 1.

Table 1: Number of CT examinations per patient by time period.

Time period	Lymphoma type		
	All lymphomas (n = 50)	HD (n = 19)	NHL (n = 31)
Before treatment	3.4 (1-6)	3.5 (2-6)	3.3 (1-6)
During chemotherapy	4.9 (0-24)	4.7 (0-13)	5.0 (0-24)
Radiotherapy planning	1.1 (0-3)	1.7 (0-3)	0.7 (0-3)
After treatment	4.0 (0-14)	4.1 (0-1)	3.9 (0-14)
All periods	13.3 (3-29)	14.0 (5-26)	12.9 (3-29)

Footnote. Value outside the parentheses is a mean number of examinations, values in parentheses - the interval.

In the course of chemotherapy CT was most often performed after 4 cycles, followed in descending order of frequency after 6, 2 and 8 cycles (Figure 1).

Multiplicity of greatest number of CT examinations to two chemotherapy cycles is explained by the fact that to determine tumor sensitivity to a specific schema of chemotherapy at least two cycles must be conducted. In the absence of treatment effect

as seen with CT, chemotherapy schema might be changed with next CT after two successive cycles.

Data on the number of CT examinations by body region performed during the entire period of diagnosis, treatment and monitoring are presented in Table 2. CT of the thorax was the most often examination regardless of lymphoma type followed in the order of decreasing frequency by CT of abdomen, pelvis and neck.

Table 2: Number of CT examinations by body region.

Body region	Lymphoma type		
	All lymphomas (n = 50)	HD (n = 19)	NHL (n = 31)
Neck	55 (9)	32 (13)	23 (6)
Thorax	252 (40)	113 (45)	139 (37)
Abdomen	190 (30)	64 (25)	126 (34)
Pelvis	128 (21)	42 (17)	86 (23)
All exams	625 (100)	251 (100)	374 (100)

Footnote. Value outside the parentheses is a number of exams, value in parentheses is a percentage of the total number of exams in this type of lymphoma.

Based on data on number of CT examinations by body region effective dose per patient has been calculated (Table 3).

Table 3: Effective dose from CT examinations in mSv per patient by time period.

Time period	Lymphoma type		
	All lymphomas (n = 50)	HD (n = 19)	NHL (n = 31)
Before treatment	23.0 (6.9-43.4)	23.8 (13.9-35.6)	22.5 (6.9-43.4)
During chemotherapy	32.8 (0-173.6)	31.9 (0-88.2)	33.4 (0-173.6)

Radiotherapy planning	4.7 (0-16.5)	6.5 (0-16.5)	3.6 (0-14.8)
After treatment	26.1 (0-100.7)	25.4 (0-77.3)	26.5 (0-100.7)
All periods	86.7 (21.7-209.2)	87.6 (34.6-176.8)	86.1 (21.7-209.2)

Footnote. Value outside the parentheses is a mean dose, values in parentheses - the interval.

The collective effective dose in this study was 4.3 Sv, the mean dose per patient - 86.7 mSv and was not different in HD and NHL. 37 (74%) patients received more than 50 mSv during the entire time period, 14 (28%) patients - more than 100 mSv, 6 (12%) patients - more than 150 mSv and 1 (2%) patient - more than 200 mSv. The contribution of the main types of CT examinations by body region to collective radiation dose is shown in Figure 2.

According to ICRP at doses above 100 mSv the risk of deterministic effects of irradiation and of the development of cancer increases. For this reason, the maximum value for a reference level is 100 mSv incurred either acutely or in a year [3]. In our study, effective dose accumulated during one year from initial CT examination exceeded 100 mSv in 6 patients. 3 of these patients had HD and 3 others NHL; one patient had stage III disease and 5 patients stage IV; 6 cycles of chemotherapy were prescribed to one patient, 8 cycles to three, 12 and 18 cycles to one patient each. It's obvious that this group of patients had most advanced disease and most intensive treatment prescribed which explains a big number of CT scans and a high level of irradiation.

Given the collective radiation dose of 4.3 Sv in 50 patients, 0.176 additional cases of cancer associated with exposure during CT examinations can be expected which is equivalent to risk of 0.35% or 1 per 256 patients.

In patients with systemic oncologic diseases such as lymphoma who underwent multiple CT examinations during course of diagnosis, treatment and follow-up potential of other non-irradiating diagnostic imaging techniques such as diffusion-weighted MRI should be evaluated (Figures 3-6).

Images for this section:

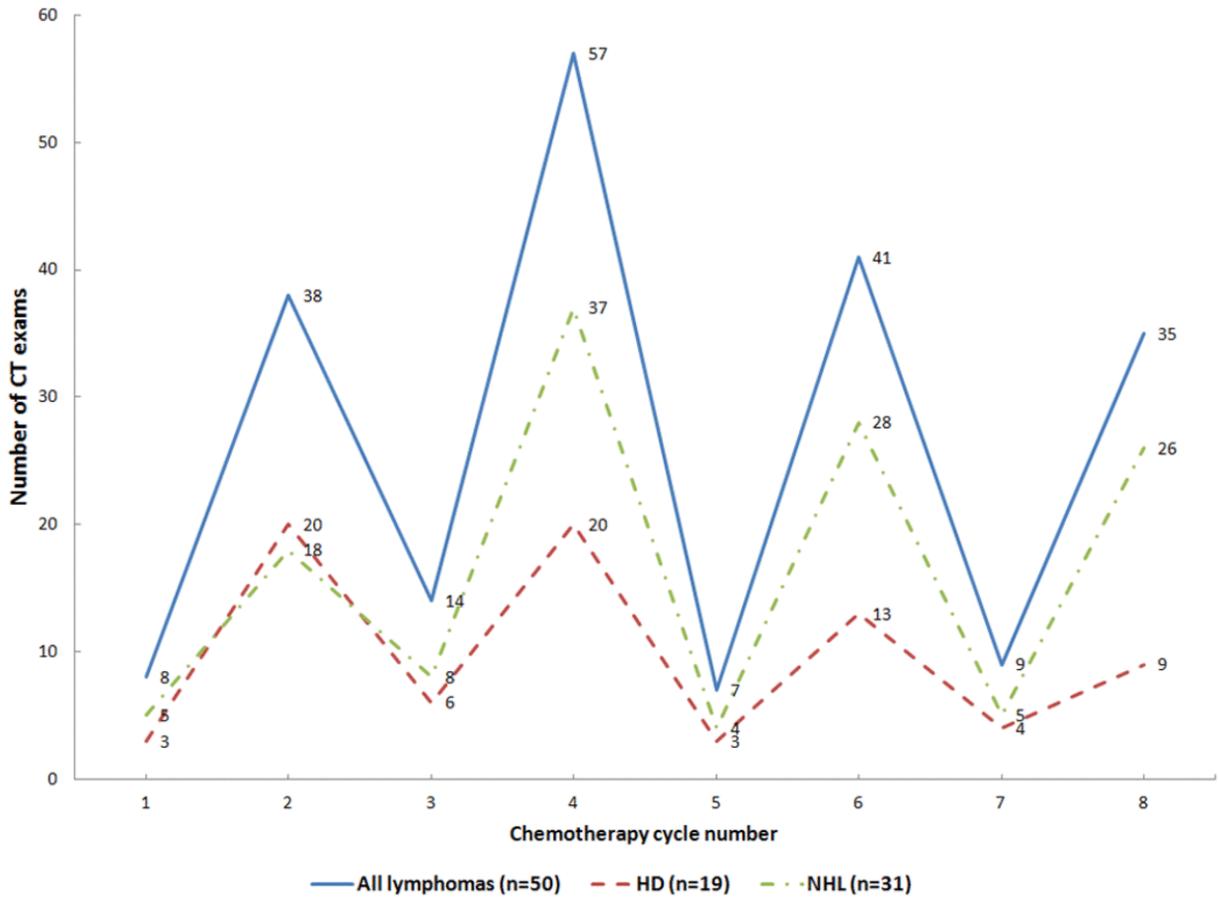


Fig. 1: Number of CT exams after the corresponding cycle of chemotherapy. The numbers next to the charts nodes are number of exams.

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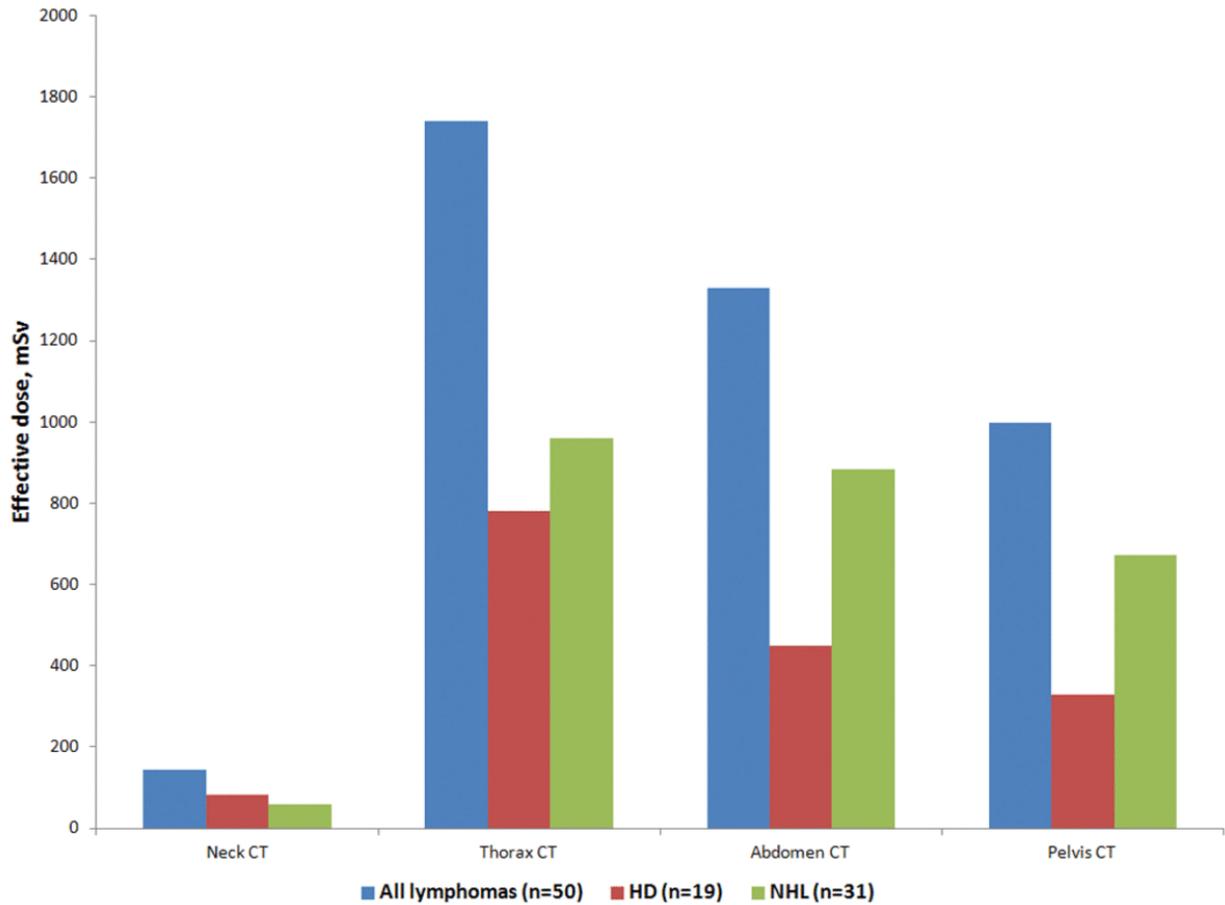


Fig. 2: The collective effective dose from main types of CT examinations.

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Fig. 3: 28 y. o. male patient with HD. Whole body diffusion-weighted MRI was performed before start of treatment. T1-weighted whole body image.

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Fig. 4: The same patient as on Figure 3. Diffusion-weighted MRI whole body MIP image.

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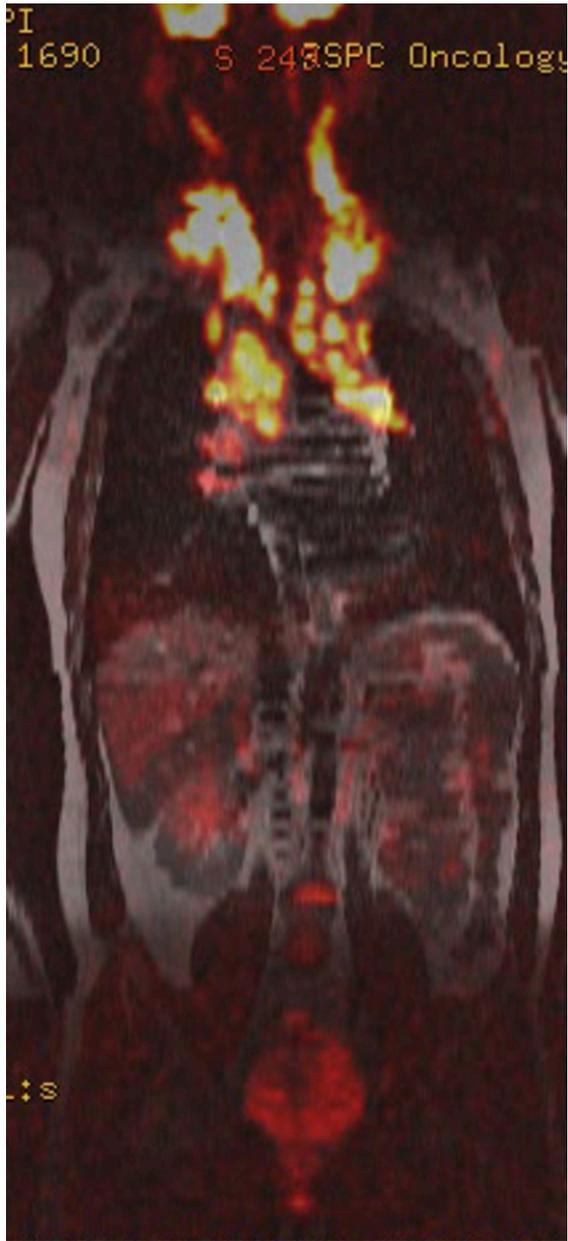


Fig. 5: The same patient as on Figure 3. Fused T2-weighted and diffusion-weighted whole body images with color mapping.

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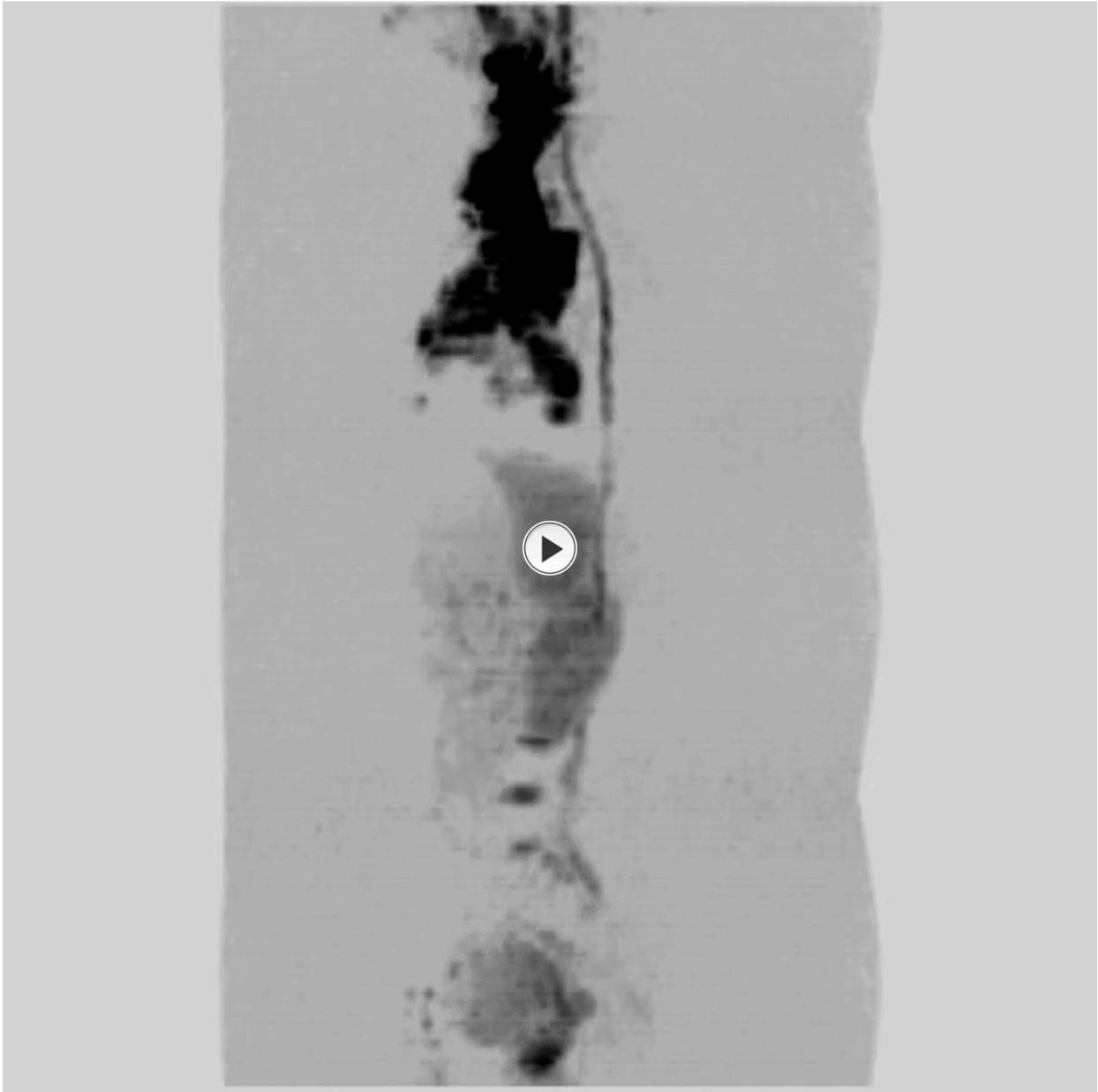


Fig. 6: The same patient as on Figure 3. Rotational whole body diffusion-weighted MRI inverted gray scale MIP video (PET-like).

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Conclusion

In patients with lymphoma treated in our institution in 2010-2011 it were performed 13.3 CT exams in average (interval 3-29 exams) per patient during entire period of diagnosis, treatment and follow-up. Biggest proportion of CTs was performed during chemotherapy followed by exams after the end of treatment. Thoracic CT was the most often examination. Mean cumulative effective dose was 86.7 mSv (interval 21.7-209.2 mSv) per patient. Attributable risk of cancer was 0.176 for the whole group equaling 1 additional cancer case per 256 patients. Our findings on attributable to CT risk of developing cancer correspond to the data of other authors [6-8]. However, the attributable risk of cancer is a quite low compared to the baseline risk of getting cancer. In addition, the value of attributable risk cannot be applied at the level of the individual patient.

In conclusion, repeated CT exams in patients with lymphoma result in a relatively high cumulative effective dose which may exceed 200 mSv. In this regard, it is advisable to consider the use of other non-irradiating radiological modalities such as MRI with diffusion-weighted imaging. Another important way of reducing patient dose is to optimize CT scanning protocols.

Personal information

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