https://doi.org/10.17816/mechnikov44920

HOW CT RECONSTRUCTION PARAMETERS EFFECT MEASUREMENT ERROR OF PULMONARY NODULES VOLUME

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For citation: Alderov ZA, Rozengauz EV, Nesterov DV. How CT reconstruction parameters effect measurement error of pulmonary nodules volume. *Herald of North-Western State Medical University named after I.I. Mechnikov*. 2020;12(3):73-77. https://doi.org/10.17816/mechnikov44920

Received: August 28, 2020 Revised: September 14, 2020 Accepted: September 23, 2020

◆ One of the the widely used way to follow up oncological disease is estimation of lesion size differences. Volumetry is one of the most accurate approaches of lesion size estimation. However, being highly sensitive, volumetric errors can reach 60%, which significantly limits the applicability of the method.

Purpose was to estimate the effect of reconstruction parameters on volumetry error.

Materials and methods. 32 patients with pulmonary metastases underwent a CT scanning with 326 foci detected. 326 pulmonary were segmented. Volumetry error was estimated for every lesion with each combination of slice thickness and reconstruction kernel. The effect was measured with linear regression analysis

Results. Systematic and stochastic errors are impacted by slice thickness, reconstruction kernel, lesion position and its diameter. FC07 kernel and larger slice thickness is associated with high systematic error. Both systematic and stochastic errors decrease with lesion enlargment. intrapulmonary lesions have the lowest error regardless the reconstruction parameters.

Lineal regression model was created to prognose error rate. Model standart error was 6.7%. There was corelation between model remnants deviation and slice thickness, reconstruction kernel, lesion position and its diameter.

Conclusion. The systematic error depends on the focal diameter, slice thickness and reconstruction kernel. It can be estimated using the proposed model with a 6% error. Stochastic error mainly depends on lesion size.

◆ **Keywords:** volumetry; lesion; volumetry error; pulmonary metastasis; systematic error; stochastic error; reconstruction kernel.

ВЛИЯНИЕ ПАРАМЕТРОВ РЕКОНСТРУКЦИИ КОМПЬЮТЕРНЫХ ТОМОГРАММ ЛЕГКИХ НА ПОГРЕШНОСТЬ ВОЛЮМЕТРИИ ПАТОЛОГИЧЕСКИХ ОЧАГОВ

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Для цитирования: Альдеров З.А., Розенгауз Е.В., Нестеров Д.В. Влияние параметров реконструкции компьютерных томограмм легких на погрешность волюметрии патологических очагов // Вестник Северо-Западного государственного медицинского университета им. И.И. Мечникова. – 2020. – Т. 12. – № 3. – С. 73–77. https://doi.org/10.17816/mechnikov44920

Поступила: 28.08.2020 Одобрена: 14.09.2020 Принята: 23.09.2020

◆ ***Актуальность.*** Одним из ключевых способов оценки течения онкологического процесса является анализ динамики размеров очагов. При очевидной высокой чувствительности погрешность волюметрии может достигать 60 %, что значительно ограничивает возможности применения метода.

Цель — оценка степени влияния параметров реконструкции изображений на погрешность волюметрии солидных очагов в легких.

Материалы и методы. Обследовано 32 пациента с метастазами почечно-клеточного рака в легких, у которых было обнаружено 326 очагов. Для каждого очага и переменного параметра реконструкции — толщины среза и кернеля — была рассчитана погрешность измерения. Степень влияния факторов на погрешность измерения оценивали с помощью регрессионного анализа.

Результаты. На случайную и абсолютную погрешность измерений влияют толщина среза, кернель реконструкции, локализация очага и его диаметр. Применение кернеля FC07 и увеличение толщины среза увеличивают систематическую погрешность. Обе компоненты погрешности уменьшаются с увеличением диаметра очага. Интрапульмональные очаги характеризуются наименьшей погрешностью измерений при всех параметрах реконструкции.

Для прогнозирования систематической погрешности при вычислении объема очагов различного диаметра с изменением толщины среза создана математическая модель. Стандартная ошибка модели составила 6,7 %. Выявлена связь между стандартным отклонением остатков модели (случайной погрешностью) диаметром очага, толщиной среза и кернелем реконструкции.

Заключение. Систематическая погрешность зависит от диаметра очага, толщины среза и кернеля реконструкции. Она может быть оценена с помощью предлагаемой модели с ошибкой 6 %. Случайная погрешность преимущественно зависит от диаметра очага.

◆ **Ключевые слова:** волюметрия; очаг; погрешность волюметрии; метастатическое поражение легких; систематическая погрешность; случайная погрешность; кернель реконструкции.

Introduction

Analysis of the changes in the size of a focus is one of the fundamental methods to assess the course of the oncological process [1, 6]. Focus dimensions can be estimated in several ways, such as by measuring the diameter, volume, or both dimensions in combination. Foci volumetry is a potentially more sensitive technique than linear measurements [2]. However, the measurement error can reach 60%, which limits its application considerably [3]. The measurement error depends on the size of the focus [4], filter used for image processing, and slice thickness [5].

This work aimed to assess the influence of image reconstruction parameters on the volumetric error of solid foci in the lungs.

Materials and methods

We examined 32 patients with metastatic lesions of the lungs, and a total of 326 foci were found.

Scanning and reconstruction options

All studies were performed by computed tomography using Aquilion ONE and Aquilion CX scanner (Canon Medical Systems, Japan). Scanning was performed in 64-spiral mode with the following settings: slice thickness, 0.5 mm; pitch, 1; voltage per tube, 120 kW, and automatic current control using the SureExposure software (Canon Medical Systems, Japan).

Each image was reconstructed three times with standard slice thicknesses of 0.5, 1.5, and 3 mm using reconstruction filters FC07 and FC14 and a different reconstruction level start.

Distribution of foci by localization

All identified foci were divided into groups of intrapulmonary foci (not adjacent to any of the normal structures of the chest) and contacting foci (parahilar, parapleural, and paravascular). The volumes of contacting foci could not be determined automatically, so the contours were corrected manually and therefore subjectively.

Contour imaging of the foci

The program automatically performs contour imaging of the intrapulmonary lesions; while the irregular shape of the actual lesion is reduced to the shape of an ideal sphere, its diameter is calculated, which is hereinafter referred to as the "effective diameter."

Contour imaging was performed using a program with the Seg3d semi-automatic contouring function. The radiologist visually assessed fitting of the normal structures of the lung and chest

wall into the contour of the focus and, if adherence was found, corrected the contour manually to refine the measurement.

Estimation of measurement error

For each focus and slice thickness–reconstruction kernel combination, the measurement error was calculated as the difference between the measured volume and the reference volume. To estimate the measurement error, the volume determined on the reconstructed images with a slice thickness of 0.5 mm and an FC14 filter was set as a reference. The degree of influence of factors on the measurement error was assessed through regression analysis. Then, the resulting model was used to plan and determine the systematic component of the measurement error, as well as the random component, based on the variability of the distribution of the model residuals.

Results

The influence of the reconstruction parameters on the volumetric results was evaluated. The graph presented in Fig. 1 demonstrates the dependence of the volume measurement error and the effective diameter on the filters and focus types used. Three vertical columns (from left to right) demonstrate reconstructions performed with a thickness of 0.5, 1.5, and 3.5 mm. Reconstruction kernels FC07 and FC14 were analyzed in two horizontal rows (from top to bottom). In each field, on the abscissa scale, the focus diameter ranges from 0 to 30 mm, and the ordinate scale shows the relative measurement error. Colored dots indicate options for focal localization.

The graph shows that both the stochastic and absolute measurement errors are influenced by the slice thickness, reconstruction kernel, focus localization, and diameter. When a FC07 kernel is used and the slice thickness is increased, the systematic error increases. Both components of the error decrease with an increase in the focus diameter. Intrapulmonary foci are characterized by the smallest measurement error for all reconstruction parameters.

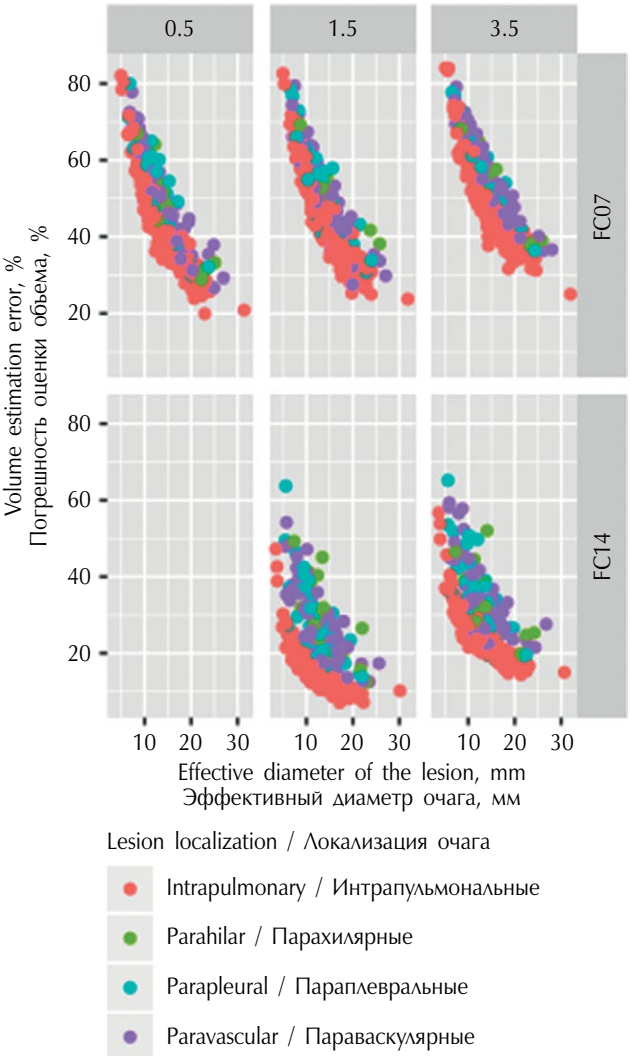

Fig. 1. The dependence of volume estimation systematic error on effective diameter of the lesion, reconstruction kernel and the lesion localization

Рис. 1. График зависимости систематической погрешности оценки объема от эффективного диаметра очага, кернеля реконструкции и локализации очага

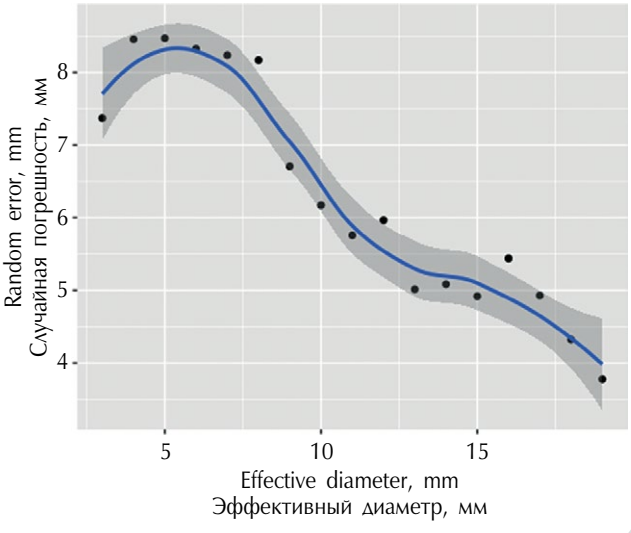

Fig. 2. The dependence of the volume estimate random error on the effective lesion diameter

Рис. 2. График зависимости случайной погрешности оценки объема от эффективного диаметра очага

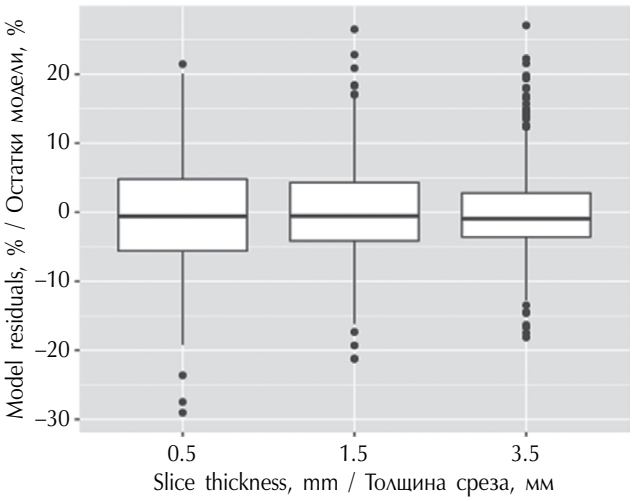

Fig. 3. The dependence of volume estimate random error from slice thickness

Рис. 3. График зависимости случайной погрешности оценки объема от толщины среза

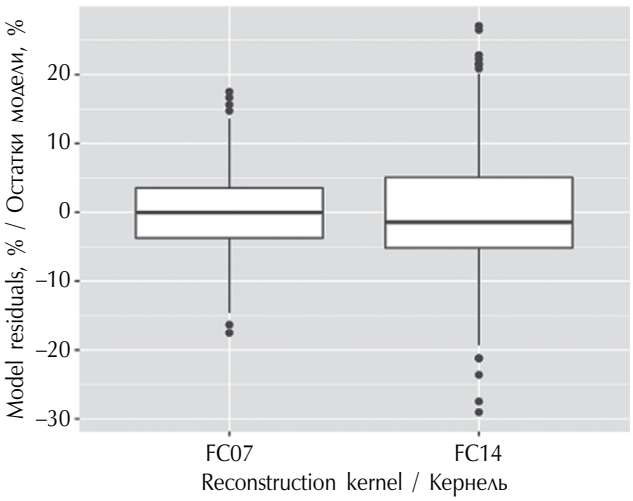

Fig. 4. The dependence of volume estimate random error on the reconstruction kernel

Рис. 4. График зависимости случайной погрешности оценки объема от кернеля реконструкции

To predict the systematic error in calculating the focus volume of various diameters with changes in the slice thickness, the following mathematical model was created:

$$\Delta V = 3 \cdot \text{Thickness} + 183/\text{Diameter} + \\ + 26_{\text{if FC07}} + 23.$$

All model coefficients were statistically significant ($p < 0.001$). The coefficient of the model determination was 0.85, and the standard error of the model was 6.7%. A relationship was found among the standard deviations of the model residuals (stochastic error), focus diameter, slice thickness, and reconstruction kernel (Fig. 2).

The stochastic error was 6.84 mm when 6 mm of diameter, 1-mm slice thickness, and FC14 kernel were used. It did not change with a decrease in diameter, but decreased by 0.09 mm with every 1-mm increase in diameter. An increase in the slice thickness causes a decrease in the standard deviation of the model residuals (Fig. 3).

The stochastic error in estimating the volume was reduced by 0.5% for each 1-mm increase in slice thickness. When the FC07 reconstruction kernel was used, the stochastic error decreased by 2.5% (Fig. 4)

Discussion

Analysis of the lesion size is a key step in assessing treatment outcomes and is important for the development of treatment guidelines. Determining dimension measurement error is critical to maintaining confidence in the reliability of data. Moreover, it is important to determine the components of this error, namely, systematic and random errors. A random measurement error directly determines the threshold value of the size dynamics, below which the real size dynamics cannot be distinguished from the measurement error.

The dynamics beyond the limits of the random measurement error also does not always indicate that it is possible to estimate the real change in these dimensions because different systematic errors are possible during measurement. In these cases, noticeable changes in sizes may be associated with different systematic errors in estimating the volumes of the foci.

Measurement errors depend on the size of the focus [4, 9], area of contact with other soft tissue structures, and scanning parameters. In our proposed model, both systematic and random components of the measurement error can be predicted. Thus, the proposed model can be used to compare the images constructed using different reconstruction parameters.

According to our data, the use of the FC07 kernel when assessing the focus volume with a diameter of 10 mm is associated with an increase of 26% in the systematic error and of 7% in the stochastic error. During case follow-up, if the first images were obtained using FC14 and the second images were obtained using FC07,

the volume of the focus must increase by at least 26 + 7 = 33% so that the registered changes can be taken as a significant increase. A difference of less than 26 – 7 = 19% means that the focus has not increased, but decreased.

The estimates obtained using the model are consistent with the experimental results of Wormanns et al. [7] and Gietema et al. [8]. In both studies, patients with small lung metastases were examined twice on the same day. All other factors did not change. In both cases, the 95% confidence intervals of foci with a diameter of up to 10 mm were comparable, which was approximately ±25%.

Phantom studies have shown that the standard deviation of measurements ranges from 4% to 28%, depending on the lesion diameter [3].

Conclusions

The results of this study suggest that systematic error depends on the focus diameter, slice thickness, and reconstruction kernel. It can be estimated with an error of 6% using the proposed model. The stochastic error mainly depends on the focus diameter.

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