ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN - POLONIA
VOL. LX, N 2, 176 SECTIO D 2005

2nd Department of Radiology, Medical University of Lublin

MAREK PASŁAWSKI, EWA KURYS, JANUSZ ZŁOMANIEC

Automatic CT volume assessment of lung tumors – determining the optimal density threshold

The optimal frequency of screening to detect stage IA disease is dependent not only on the time at which tumors metastasize but also on the range of growth rates of lung cancers (4)

The standard method for assessing the response of a tumor to treatment is to determine its change in maximum cross-sectional area. However two-dimensional measurements may misrepresent change in tumor size by disregarding alteration to the third dimension. More accurate determination of tumor size change may by obtained using three-dimensional volume measurements. Until recently tumor volume measurements were not easily achieved. With the advent of helical CT volumetric data acquisition within a single breath hold can by now obtained. Tumor volume measurements have become easier using new software, and may by automated (5).

The aim of the study is to determine the proper density threshold for automatic lung tumors volumetric measurements.

MATERIAL AND METHODS

Material comprises a group of five patients with lung tumors. In all patients the CT chest scanning was performed in 5 mm thick axial sections. The examination was performed before and after administering of contrast agent (Ultravist, 5 ml/kg). After examination the volume of the tumors was assessed using dedicated software enabling both manual and automatic assessment of the volume. During manual measurement the border of the tumors were precisely delineated manually using mouse on each slice, then the volume of the tumor was calculated. The manual measurements were used as reference values. Automatic volume measurements were performed using 4 different density thresholds: –250 HU, –200 HU, –150 HU and –100 HU. The results of the automatically achieved values were compared to reference, manual measurement.

RESULTS

Four tumors were relatively small, below 2 cm^3. Three of them were round, and regular (Fig. 1AB). One of them was irregular (Fig. 2AB), in the right upper lobe. On axial CT section the contact with the chest wall was seen. The fifth tumor was much larger, about 21 cm^3. It was localized in the right lung and was also irregular (Fig. 3AB).

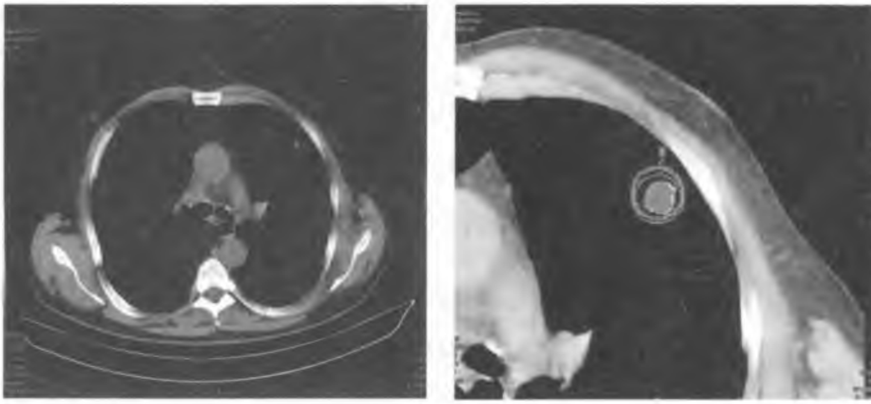

Fig. 1. A – small regular round tumor in the left lung lobe. B – enlarged image of the volume measurement, coded with colors. Different colors represent measurements with different density values

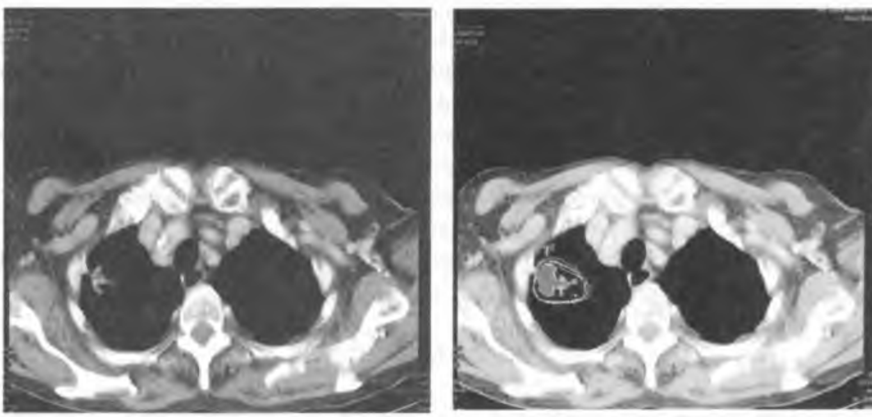

Fig. 2. A – irregular tumor of the right lung, connected with the chest wall volume measurement, coded with colors. Different colors represent measurements with different density values. Yellow lines surrounding the measured structure separate the tumor from the chest wall

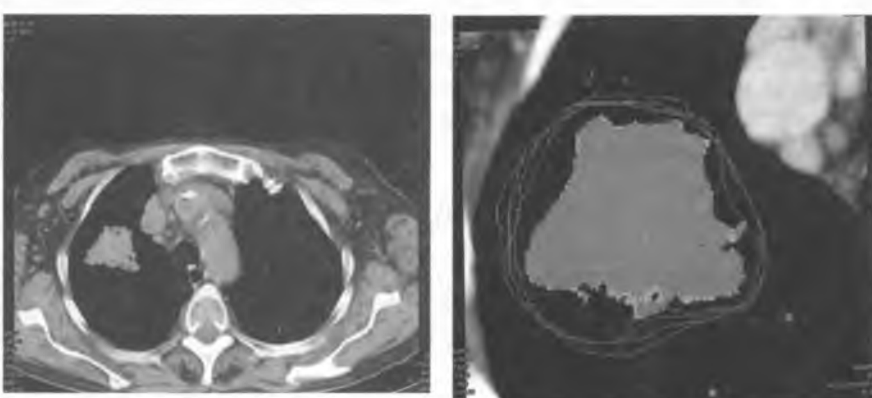

Fig. 3. A – large irregular tumor of the right lung. B – enlarged image of the volume measurement, coded with colors. Different colors represent measurements with different density values

Table 1. The results of the manual and automatic volume measurements

Number	Reference manual measurement (cm^3)	Automatic measurements with thresholds			
		–250 HU	–200 HU	–150 HU	–100 HU
1	0.67	0.74	0.68	0.55	0.39
2	1.21	1.66	1.34	0.97	0.65
3	0.91	1.07	0.91	0.74	0.57
4	1.20	1.80	1.49	1.15	1.02
5	21.27	23.57	21.71	21.10	19.76

For 4 measured tumors the result of reference manual measurement was between automatically measured values for –200 and –150 HU (marked in Table 1). For one tumor the result of manual measurement was the same as the result of the automatic measurement with the –200 HU threshold.

DISCUSSION

The volume measurements determined from helical CT data with appropriate image processing software are accurate and reproducible (5).

Radiologic assessment of tumors with the use of volumetric imaging technologies such as helical CT and MR imaging before and after the start of therapies, permits accurate quantification of tumor burden, volumetric images acquisition with modern MR images and helical CT scanners allows precise three-dimensional measurement of tissue volumes. Volumetric measurement provides better representation of tumor burden, and may by superior to conventional tumor measurement techniques. For one-dimensional measurement according to RECIST criteria the >30% reduction of the tumor diameter represent partial response, and >20% increase in diameter represent disease progression. For bidimensional measurement >50% increase in cross product represent partial response, and >25% increase in cross product represent progression. For volumetric measurements >65% reduction in volume represent partial response and >44% increase in volume represent the progression (6).

Almost all data on the growth rate of lung cancers are derived from chest radiographic studies. These studies have limitations because the authors assumed the lesions were spherical and used the mean diameter to calculate the doubling time (DT) of lesions on serial chest radiographs. Few data have been published in which CT was used to measure serial volumes of lung cancers prior to treatment (5).

Hasegawa et al. measured the doubling time of nodules on successive CT images in 61 patients whose nodules were later proven to be cancerous and found that DT ranged from 52 to 1,733 days (mean, 452 days; median not reported). In their study, however, the largest nodular cross-sectional area, not volume, was used in DT calculations, not all tumors were stage I at diagnosis, and 80% of tumors were adenocarcinomas (3).

The only large (61 patients) series to date used the maximum cross-sectional area of the tumor and not its volume to calculate the growth rate. Growth rates derived from maximum tumor cross-sectional areas could not be used to distinguish benign from malignant nodules but that growth rates derived from CT volumetric measurements of CT images could be used. Volumetric measurement is necessary to evaluate tumor growth, since growth may be asymmetrical in not just two dimensions, but in all three (5).

Aoki et al. measured tumor growth at serial CT examinations in 10 patients with adenocarcinoma prior to treatment but used only mean tumor diameters, not volume, and did not separate the CT-derived results from radiographic measurements (1). Yankelevitz et al. used automated three-dimensional reconstruction of CT images to measure the growth of small nodules in 13 patients; in their study, all benign tumors had a DT greater than 395 days, and all malignant tumors had a DT less than 178 days; the use of maximum cross-sectional area did not separate benign and malignant tumors (7).

There is no statistically significant relationship between tumor size and survival in patients with stage IA non-small cell lung cancer (non-small cell lung cancer; i.e, lesions < 3 cm) (2).

Volumetric tumor assessment is important. Manual measurement is based on tracing tumor margins on each section. Tracing individual tumor margins on each slice is time consuming. Therefore, the most modern CT scanners are equipped with automatic volume calculating software. In the case of lung tumors it is especially useful, due to high density contrast. Automatic volume measurement is density dependent – the threshold densities influence the measured value. Therefore, determining of the threshold density providing reliable measurement is essential.

CONCLUSIONS

The volumetric tumor measurements are important in lung tumor staging as well as assessment of the response to the chemo-and/or radiotherapy. The lung tumors are suitable especially for automatic volume measurements, based on density threshold. The main problem is to choose the proper density value, ensure the correct volume measurements. The results of our study clearly show that density threshold value between –200 HU and –150 HU are the most suitable for automatic measurement of the lung tumor volume.

REFERENCES

1. Aoki T. et al.: Evolution of peripheral lung adenocarcinomas: CT findings correlated with histology and tumor doubling Time. AJR, 174, 763, 2000.
2. Patz E. F. et al.: Correlation of Tumor Size and Survival in Patients with Stage IA Non-small Cell Lung Cancer. Chest, 117, 1568, 2000.
3. Hasegawa M. et al.: Growth rate of small lung cancers detected on mass CT screening. Br. J. Radiol., 73, 1252, 2000.
4. Helen T. Winer-Muram H. T. et al.: Volumetric growth rate of stage I lung cancer prior to treatment: Serial CT scanning. Radiology, 223, 798, 2002.
5. Sohaib S. A. et al.: CT assessment of tumor response to treatment: comparison of linear, cross-sectional and volumetric measures of tumor size. Br. J. Radiol., 73, 1178, 2000.
6. Prasad S. R. et al.: CT tumor measurement for therapeutic response assessment: Comparison of unidimensional, bidimensional, and volumetric techniques – initial observations. Radiology, 225, 416, 2002.
7. Yankelevitz D. F. et al.: Small pulmonary nodules: volumetrically determined growth rates based on CT evaluation. Radiology, 217, 251, 2000.

SUMMARY

The aim of the study is to determine the proper density threshold for automatic lung tumors volumetric measurements. The material comprises a group of five patients with lung tumors. In all patients the CT chest scanning was performed in 5 mm thick axial sections. The examination was performed before and after administering of contrast agent (Ultravist, 5 ml/kg). After examination the volume of the tumors was assessed using dedicated software enabling both manual and automatic assessment of the volume. During manual measurement the border of the tumors were precisely delineated manually using mouse on each slice, then the volume of the tumor was calculated. The manual measurements were used as reference values. Automatic volume measurements were performed

using 4 different density thresholds: –250 HU, –200 HU, –150 HU and –100 HU. The results of the automatically achieved values were compared to reference, manual measurement. Four tumors were relatively small, below 2 cm^3. Three of them were round, and regular. One of them was irregular, in the right upper lobe. On axial CT section the contact with the chest wall was seen. The fifth tumor was much larger, about 21 cm^3. It was localized in the right lung and was also irregular. For four measured tumors the result of reference manual measurement was between automatically measured values for –200 and –150 HU. For one tumor the result of manual measurement was the same as the result of the automatic measurement with the –200 HU threshold. The volumetric tumor measurements are important in lung tumor staging as well as assessment of the response to the chemo-and/or radiotherapy. The lung tumors are suitable especially for automatic volume measurements, based on density threshold. The main problem is to choose the proper density value, ensure the correct volume measurements. The results of our study clearly show that density threshold value between –200 HU and –150 HU are the most suitable for automatic measurement of the lung tumor volume.

Automatyczny pomiar objętości guzów płuc – określenie optymalnej wartości densyjności progowej

Celem pracy jest określenie właściwego progu densyjności do automatycznej oceny objętości guzów płuc. Materiał stanowiła grupa pięciu pacjentów z guzami płuc. U wszystkich pacjentów wykonywano badanie TK klp w przekrojach grubości 5 mm. Badanie wykonywano przed i po podaniu środka kontrastowego. Wtórnie mierzono objętość guzów, wykorzystując oprogramowanie umożliwiające ocenę manualną i automatyczną. Podczas pomiarów ręcznych precyzyjnie obrysowywano zarysy każdego guza na każdym przekroju TK. Pomiary automatyczne wykonywano dla progowych densyjności –250, –200, –150 i –100 jH. Cztery guzy były względnie małe, poniżej 2 cm^3, trzy z nich były okrągłe i regularne. Jeden był nieregularny. Na przekrojach osiowych TK stwierdzono kontakt ze ścianą klp w tym przypadku. Piąty guz były duży, o objętości ok. 21 cm^3, był również nieregularny. Objętości pomiarów ręcznych dla czterech guzów mieściły się w zakresie pomiarów automatycznych dla densyjności progowych –200 i –150 jH. Objętość jednego guza mierzona ręcznie była równa pomiarowi automatycznemu dla gęstości progowej –200 jH. Ocena objętościowa guzów jest ważna, zarówno w ocenie stopnia zaawansowania, jak i w ocenie odpowiedzi na leczenie i progresji zmian. Guzy płuc nadają się do pomiarów automatycznych objętości. Głównym problemem jest dobór odpowiedniej densyjności progowej zapewniającej wiarygodny automatyczny pomiar objętości. Wyniki naszych badań wskazują na to, że densyjność progowa dla automatycznych pomiarów guzów płuc powinna mieścić się w zakresie –150 do –200 jH.