ELSEVIER

Clinical Imaging 35 (2011) 123 – 126

CLINICAL IMAGING

# Pulmonary nodules: a quantitative method of diagnosis by evaluating nodule perimeter difference to approximate oval using three-dimensional CT images

Hisashi Kamiya*, Sadayuki Murayama, Yasumasa Kakinohana, Tetsuhiro Miyara

*Department of Radiology, Faculty of Medicine, University of the Ryukyus, 207 Uehara, Nishihara-cho, Okinawa 903-0215, Japan*

Received 24 February 2010; accepted 8 March 2010

**Abstract**

The purpose of this study was to investigate whether maximum nodule perimeter to the approximate oval could discriminate benign nodules from malignancy. Measurement of maximum nodule perimeter difference to the approximate oval was performed using volume-rendering images of three directions of each pulmonary nodule. The margin was then traced manually and our custom software delineated the approximate oval automatically. The maximum nodule perimeter difference was 26.5±23.3 mm for malignant and 16.6±16.9 mm for benign nodules, showing an almost statistically significant difference ($P$=.07). This study suggests that the maximum nodule perimeter difference to the approximate oval of the malignant nodules has a tendency to be longer than benign nodules.


*Keywords:* CT; Three-dimensional image; Computer-aided diagnosis; Lung cancer; Pulmonary nodule

## 1. Introduction

The morbidity and mortality of lung cancer remain high, and early detection and treatment is clinically important. A large number of pulmonary nodules are encountered with the widespread use of computed tomography (CT), and it is therefore important to precisely differentiate lung cancer from benign nodules that do not need treatment.

Differentiation between malignant and benign nodules by chest CT is primarily conducted by analysis of shape and internal structure [1–4], but it seems that radiologists' experience and diagnostic ability lead to variation in image interpretation. To remove the subjectivity of clinician interpretation, and to obtain diagnostic consistency, several differential diagnostic procedures using computer-aided diagnosis (CAD) have been developed [5–12]. Categorization of margin shape of pulmonary nodules has been established [1,2]. According to Furuya's classification, round nodules are seen in both benign and malignant lesions [1]. Fine spiculation and lobulation are frequently seen with malignancy. Polygonal shape is frequently observed in inflammatory nodules, for which constrictive change is pathognomonic [1,2]. We propose that when nodules are more circular, and their margins are smoother, the more likely the lesion is to be benign. And, if we digitize this information by a mathematical calculation of circular degree, we may be able to discriminate benign from malignant nodules. Also, in calculating a nodular circular degree, three-dimensional evaluation rather than two-dimensional evaluation may be desirable.

Based on these theories, we used computer-generated oval approximations of nodules based on axial, sagittal, and coronal CT sections, and investigated whether maximum nodule perimeter to the approximate oval is an

* Corresponding author. Department of Radiology, Faculty of Medicine, University of the Ryukyus, 207 Uehara, Nishihara-cho, Okinawa 903-0215, Japan. Tel.: +81 98 895 1160; fax: +81 98 895 1420.

*E-mail addresses:* e954123@gmail.com (H. Kamiya), sadayuki@med.u-ryukyu.ac.jp (S. Murayama), kakihana@med.u-ryukyu.ac.jp (Y. Kakinohana), mchutetsu@ybb.ne.jp (T. Miyara).

0899-7071/$ – see front matter 
doi:10.1016/j.clinimag.2010.03.007

objective means of differentiation between malignant and benign nodules.

## 2. Subjects and methods

As a retrospective study, patient consent was not required for this project at our institution.

Subjects included patients with peripheral solid pulmonary nodules measuring from 5 to 30 mm in diameter as imaged by thin-section multidetector-row CT (MDCT) in our institution from January 2000 to September 2009. The 25 malignant nodules from 25 cases ranged from 5.9 to 28.9 mm in maximal diameter (mean, 13.2 mm). They included 12 adenocarcinomas, 5 squamous cell carcinoma, 6 metastasis, 1 adenosquamous carcinoma, and 1 unclassified primary lung cancer. All nodules except one were histologically proven. One metastasis was diagnosed clinically. These cases including all metastatic cases had only one nodule, and it was difficult to diagnose their entity in the clinically setting.

The benign nodules included 33 nodules from 33 cases and ranged from 5.1 to 26.3 mm in maximal diameter (mean, 9.6 mm). Eight of 33 benign nodules were histologically confirmed by surgery or biopsy, including one sclerosing hemangioma, one tuberculoma, one non-tuberculotic mycobacteriosis, one granuloma, and four nodules without malignant cells. Twelve nodules showed no change in size over at least 2 years, and 13 nodules apparently regressed on follow-up diagnostic CT. Nodules showing pure ground glass opacity without change in size were excluded because they might have included both natures such as BAC, atypical adenomatous hyperplasia, and benign focal fibrosis.

The CT apparatus used were a four-row MDCT (Lightspeed QXi, General Electric, Milwaukee, WI) and a 64-row MDCT (VCT, General Electric; Aquilion 64 and Aquilion One, Toshiba, Tokyo). Targeted thin-section CT images of the lesions were obtained immediately after realizing the nodules in the total CT images from lung apices to lung bases. Scan parameters were variable. Subsequently, we made the volume rendering (VR) images of the nodules in three directions including axial, sagittal and coronal sections, using the imaging workstation (Advantage Windows v.3.1and v4.0, General Electric). We used a VR image instead of the maximum intensity projection method (MIP) because demonstration of the entire nodule was difficult by MIP. The VR images with high transmittance facilitated imaging the whole nodule.

The images were then transferred to a general-purpose personal computer. At first, using Furuya's shape classification of the pulmonary nodule [1], malignant and benign nodules were classified. Subsequently, we measured maximum nodule perimeter difference to the approximate oval. How to measure the maximum nodule perimeter difference to the approximate oval with our custom software is shown in Fig. 1; after the image representing the widest part of the nodule for each plane was chosen, we traced the nodal margins manually. After that, an approximate oval was automatically delineated, and the difference of nodule perimeter obtained by manual tracing to the approximate oval was calculated. The maximums in three directions of values were selected for evaluation.

We compared those numerical values between malignant and benign nodules and evaluated for a significant difference by Student's $t$ test.

## 3. Results

By Furuya's classification of malignant lesions, 12 nodules were classified as lobulated, 6 ragged, 4 round, 3 polygonal, and none spiculated. For the benign nodules, 15 nodules were classified as round, 13 polygonal, 4 lobulated, 1 spiculated, and none ragged.

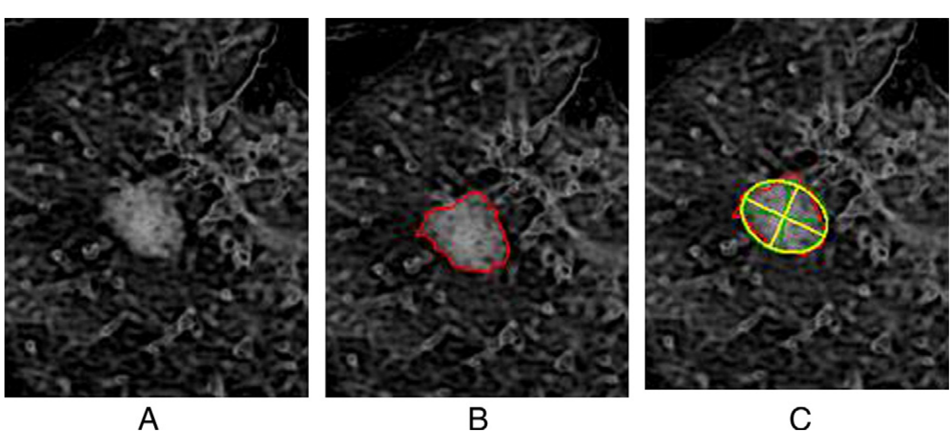


Fig. 1. (A) The nodule image with the greatest dimension on VR imaging derived from CT images is chosen. (B) The nodal margin (red line) is traced manually. (C) After that, an approximate oval was automatically delineated (yellow oval line), and nodule perimeter difference obtained by manual tracing to the approximate oval was calculated.