Chinese-German J Clin Oncol
DOI 10.1007/s10330-314-0004-x
December 2014, Vol. 13, No. 12, P567–P571

Peripheral bronchogenic carcinoma: Enhancement pattern evaluation on PACS and CT workstations

Chunlei Lv (✉)[1], Shenjiang Li[2], Changcheng Li[2], Debin Liu[2], Wenjie Liang[2], Feng Zhu[2], Yan Zhu[2], Xuefeng Cui[2]

[1] Medical Administration Division, The Eighty-eighth Military Hospital, Tai'an 271000, China
[2] Department of Imageology, The Eighty-eighth Military Hospital, Tai'an 271000, China

Received: 11 September 2014 / Revised: 14 November 2014 / Accepted: 5 December 2014

Abstract *Objective:* The aim of the study was to determine the efficiency and effectiveness of picture archiving and communication system (PACS) workstation in detecting enhancement pattern of peripheral bronchogenic carcinoma. *Methods:* The 62 patients with peripheral bronchogenic carcinoma underwent two-phase contrast material-enhanced multislices computed tomography (MSCT) of the chest in a single-breath-hold technique. Two spiral CT scans were obtained at 25 s and 90 s respectively after nonionic contrast material was administrated via the antecubital vein at a rate of 4 mL/s by using an autoinjector. Precontrast and postcontrast attenuation on every scan were measured on PACS and CT workstations respectively and peak height was calculated. Enhancement pattern was evaluated on the image obtained at 90 s after injection of contrast medium on PACS and CT workstations respectively. *Results:* No statistically significant difference in precontrast attenuation, postcontrast attenuation at 25 s and 90 s was found between these measured on a PACS workstation [(40.21 ± 7.03) HU; (55.53 ± 11.09) HU; (75.95 ± 13.45) HU] and those [(39.01 ± 8.95) HU; (56.01 ± 10.91) HU; (76.03 ± 11.95) HU] on a CT workstation (t = 1.140, P = 0.256 > 0.05; t = 1.580, P = 0.149 > 0.05; t = 1.505, P = 0.150 > 0.05). The peak height that calculated on a PACS workstation was 35.74 HU (20 HU). There was not statistically significant difference in peak height between that calculated on a PACS workstation and that on a CT workstation [(37.02 ± 12.05) HU; t = 2.001, P = 0.099 > 0.05]. The tumors showed same enhancement pattern on PACS workstation and CT workstation. Of the 62 cases, 38 showed homogeneous enhancement, 17 showed heterogeneous enhancement, five showed peripheral enhancement, two showed central enhancement, at 90 s. The enhancement pattern revealed on PACS workstation was consistent with feature of peripheral bronchogenic carcinoma. *Conclusion:* The efficiency and effectiveness of PACS workstation is as same as those of CT workstation in detecting enhancement pattern of peripheral bronchogenic carcinoma.

Key words peripheral bronchogenic carcinoma; picture archiving and communication system (PACS); tomography, X-ray computed; workstation

At present, lung cancer is the most common malignancy all over the world and accounts for the greatest number of cancer-related deaths in both men and women [1–3]. Early diagnosis of bronchogenic carcinoma that are still at an early stage is crucial for cure and prognosis [3]. Computed tomography (CT) is the most common and effective imaging modality used to differentiate solitary pulmonary nodules (SPNs). It is often difficult to differentiate SPNs by morphologic features only, enhanced CT is helpful in doing so [4–6]. With the development of the information level of medical industry, picture archiving and communication system (PACS) has become an important part of the practice of modern medical radiology. With the development of technology, it is convenient to reform image and detect enhancement pattern of peripheral bronchogenic carcinoma on a PACS workstation [7]. To our knowledge, it has not been reported in previous studies to compare the enhancement pattern of peripheral bronchogenic carcinoma detected on a PACS workstation with those on a CT workstation.

The aim of this study was to determine the efficiency and effectiveness of PACS workstation in detecting enhancement pattern of peripheral bronchogenic carcinoma by comparing the enhancement pattern of peripheral bronchogenic carcinoma detected on a PACS workstation with those on a CT workstation.

Patients and methods

Patients

Patients were selected according to the following criteria: (a) being confirmed histologically, (b) absence of

Correspondence to: Chunlei Lv. Email: lishenjiang1971@sina.com

contraindication to the administration of contrast material, and (c) probable ability to cooperate with the procedure. Sixty-five patients with peripheral bronchogenic carcinoma met the criteria and underwent double-phase contrast material-enhanced multislices computed tomography (MSCT) between 2012 and 2013. Three patients because of beam-hardening artifact or substantial cardiac motion were excluded from the study.

Sixty-two patients [32 men, 30 women; age range 34–76 years; mean age (56.83 ± 10.66) years] with peripheral bronchogenic carcinoma 1.82–8.78 cm [mean, (5.52 ± 1.02) cm] were studied. Final diagnosis were confirmed histologically by means of surgery or CT-guided transthoracic needle aspiration biopsy. The 62 patients (adenocarcinoma in 30 patients, squamous cell carcinoma in 15 patients, adenosquamous carcinoma in eight patients, small cell lung cancer in six patients, and bronchioloalveolar carcinoma in three patients) were included into the study.

Protocol

Before the examination began, patients were carefully instructed in and practiced the breath-holding technique to reproduce precisely the same degree of inspiration for each scan series. All CT scans were obtained with a commercially available system (LightSpeed, General Electric Medical Systems, VCT).

One precontrast scan and two postcontrast spiral CT scans (tube voltage 120 kV, tube current 80–350 mA, field of view 220 mm a 0.625 mm collimation, and pitch 0.984:1) were performed during suspended full inspiration within a single breath hold. Iodinated, lowosmolar, nonionic contrast material (ioversol injection, 300 mg iodine/mL, Mallinckrodt Inc. St. Louis, USA) was administrated via the antecubital vein at a rate of 4 mL/s for a total 90 mL by using an autoinjector. The section thickness was 5 mm. The two spiral CT scans were obtained beginning at 25 s and 90 s after injection of contrast medium respectively. A normal reconstruction algorithm without edge enhancement (window width, 350 HU; window level, 40 HU) was used for scanning.

Data analysis

Precontrast and postcontrast attenuation on every scan were measured on PACS and CT workstations with a 5 megapixel (MP) liquid crystal displays (LCDs) respectively and peak height was calculated. Enhancement pattern was evaluated on the image obtained at 90 s after injection of contrast medium on PACS and CT workstations respectively. The region of interest was as large as possible to minimize noise but with care to avert partial-volume effect. According to this criterion, the area of the region of interest was about 60% of the area of the lung nodule but with care to avert calcification and necrosis. If there was beam hardening from adjacent bone or substantial artifact from cardiac motion to create rapid changes of attenuation, the image was eliminated from data analysis. Precontrast and postcontrast attenuation on every scan was recorded and peak height was calculated. Peak height was defined as total attenuation minus baseline precontrast attenuation.

Enhancement pattern was evaluated on the image obtained at 25 s and 90 s after injection of contrast medium respectively and classed as follows: homogeneous, if enhancement of the nodule was completely homogeneous; heterogeneous, if enhancement of the nodule was completely heterogeneous; central, if enhancement was at the inner area of the nodule; peripheral, if enhancement was at the out area of the nodule; and no enhancement, if a nodule showed no apparent enhancement (peak height < 5 HU). Two experienced chest radiologist independently measured the attenuation and determined the enhancement pattern of peripheral bronchogenic carcinoma on PACS and CT workstations respectively.

Statistical analysis

All values were expressed as a mean ± standard deviation. The significance of the difference among groups was analyzed by means of Student-*t* test. A P value less than 0.05 was considered statistically significant. All the statistical analysis were performed by SAS 9.13 software.

Results

Comparison of characteristics parameters of 62 cases with peripheral bronchogenic carcinoma measured on PACS and CT workstations

The characteristics parameters of 62 cases with peripheral bronchogenic carcinoma measured on PACS and CT workstations were shown in Table 1, and Fig. 1 and 2.

There was not statistically significant difference between the diameters of peripheral bronchogenic carcinoma that measured on PACS and CT workstations (P = 1.001, and P = 0.325 > 0.05). No statistically significant

Table 1 The characteristics parameters comparison of 62 cases with peripheral bronchogenic carcinoma

Characteristics parameters	PACS	CT
Diameter (cm)	5.52 ± 2.32 (1.82–8.78)	5.29 ± 2.12 (1.59–8.98)
Precontrast attenuation (HU)	40.21 ± 7.03 (24.20–59.20)	39.01 ± 8.95 (24.40–61.20)
Attenuation at 25 s (HU)	55.53 ± 11.09 (33.00–80.30)	56.01 ± 10.91 (34.00–79.30)
Attenuation at 90 s (HU)	75.95 ± 13.45 (53.00–99.80)	76.03 ± 11.95 (53.50–98.50)
Peak height (HU)	35.74 ± 11.95 (23.10–69.55)	37.02 ± 12.05 (24.00–70.05)

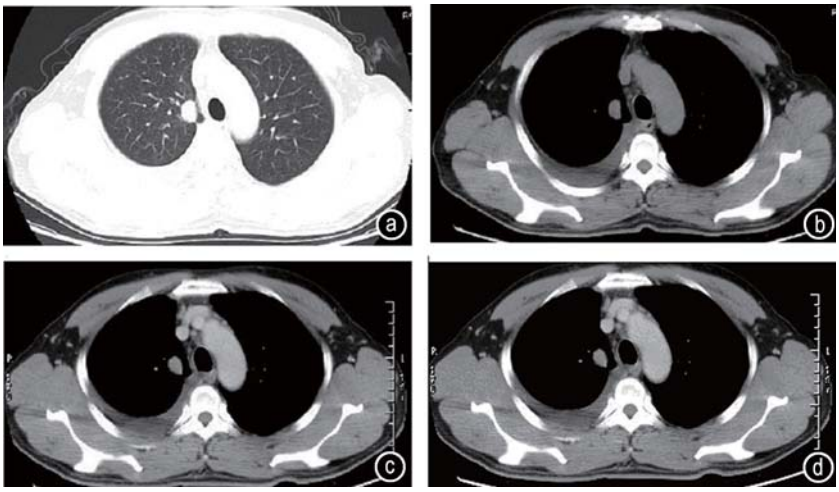

Fig. 1 The enhancement pattern of adenocarcinoma of the right upper lobe in a 43-year-old man were detected on CT workstation. (a) The image showed a lobulated tumor in the upper lobe of the right lung; (b) The image revealed a heterogeneous tumor with attenuation value 23.00 HU on the precontrast scan; (c) The lesion appeared heterogeneous enhancement at 25 s after administration of contrast material with attenuation value 32.00 HU; (d) homogeneous enhancement at 90 s after administration of contrast material with attenuation value 48.00 HU

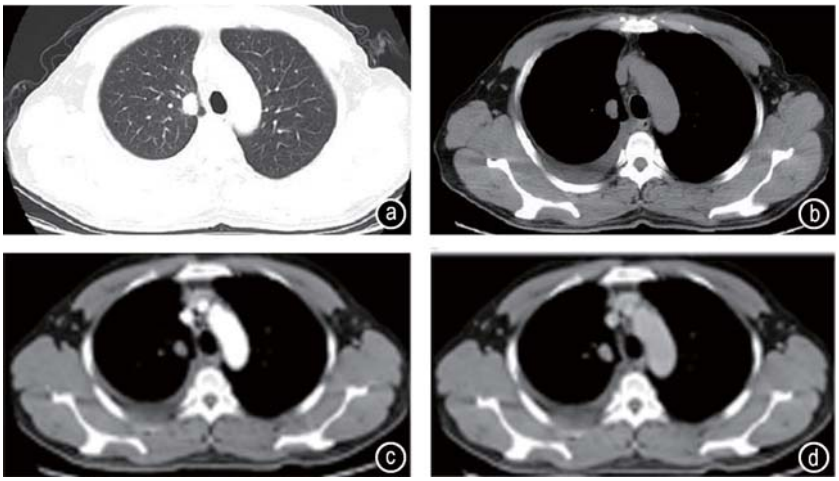

Fig. 2 The same patient as Fig. 1. The enhancement pattern of the adenocarcinoma was detected on PACS workstation. (a) The image showed a lobulated tumor in the upper lobe of the right lung; (b) The image revealed a heterogeneous tumor with attenuation value 22.00 HU on the precontrast scan; (c) The lesion appeared heterogeneous enhancement at 25 s after administration of contrast material with attenuation value 33.00 HU; (d) Homogeneous enhancement at 90 s after administration of contrast material with attenuation value 50.00 HU

difference in precontrast attenuation was found between that measured on a PACS workstation and that on a CT workstation (t = 1.140, P = 0.256 > 0.05). There was not statistically significant difference in the attenuation at 25 s between that measured on a PACS workstation and that on a CT workstation (t = 1.580, P = 0.149 > 0.05). No statistically significant difference in the attenuation at 90 s was found between that measured on a PACS workstation and that on a CT workstation (t = 1.505, P = 0.150 > 0.05). There was not statistically significant difference in the peak height of peripheral bronchogenic carcinoma between that measured on a PACS workstation and that on a CT workstation (t = 2.001, P = 0.099 > 0.05).

The enhancement patterns of the peripheral bronchogenic carcinoma

The 62 cases with peripheral bronchogenic carcinoma showed the same enhancement patterns on PACS workstation and CT workstation. Of the 62 cases, 38 showed homogeneous enhancement, 17 showed heterogeneous enhancement, five showed peripheral enhancement, and two showed central enhancement, at 90 s.

Discussion

Lung cancer is the most common malignancy all over the world and accounts for the greatest number of cancer-related deaths in both men and women [1–3]. Differentiation between benign and malignant SPNs using non-invasive methods is important in order to avoid invasive examinations. The 5-year survival rate for bronchogenic carcinoma that are still at an early stage after surgery is more than 90%, while 5-year survival rate at an advanced stage is less than 5% [8]. Early diagnosis of bronchogenic carcinoma that are still at an early stage is crucial for cure and prognosis [8]. At present, tumor has been proved to be a kind of disease depending on angiogeneous [9]. Currently microvessel density (MVD) count is considered the standard for quantification of angiogenesis in histologic studies [4]. Tumor angiogenesis is the process by which

new blood vessels are formed from the existing vessels in a tumor. The changes in the tumor vessels cause changes in hemodynamics and capillary permeability. Tumor angiogenesis promotes tumor growth, progression and metastasis and shows good correlation with poor prognosis [5]. Angiogenesis research is now being translated from laboratory to clinical application. The clinical development of antiangiogenesis therapy for cancer is advancing rapidly.

Computed tomography (CT) is the most common and effective imaging modality used to differentiate solitary pulmonary nodules (SPNs). The peak height of bronchogenic adenocarcinoma correlated positively with MVD [4]. It is often difficult to differentiate SPNs by morphologic features only, enhanced CT is helpful in differentiating SPNs and in assessing no-surgical treatment response in bronchogenic carcinoma preliminarily. Peak height of bronchogenic carcinoma after no-surgical treatment were significantly lower than that of bronchogenic carcinoma without any therapy [5]. Therapeutic effect may be underestimated with use of changes in tumor size despite of changes in enhancement pattern in assessing no-surgical treatment response in bronchogenic carcinoma [5]. Recent new-generation multislices spiral computed tomography (MSCT) scans patients much faster than single-slice CT, with higher temporal resolution, thinner slice thickness, more data, more images, and lower radiation doses. With the development of MSCT, it is convenient to construct MPR images and measure the sizes and attenuation of malignant SPNs [3, 6].

With the development of the information level of medical industry, PACS has become an important part of the practice of modern medical radiology. There are three advantages to investigate enhancement pattern of peripheral bronchogenic carcinoma on PACS workstation. First, it is not limited by the number of CT workstation. Second, many radiologists can evaluate enhancement pattern of peripheral bronchogenic carcinoma simultaneously. Third, it is convenient to discuss with other doctors. With the development of the CT and PACS technologies, more and more doctors are accustomed to work on PACS workstation.

It is common consent today, that PACS is the key technology crucial to daily clinical image operations and especially to image related basic and clinical researches. At present, the PACS has been matured from a research and developmental stage into commercial products which are provided by all major modality and health care equipment vendors. Once the decision has been made to adopt PACS instead of a film-based radiology practice, there are a number of hurdles to jump. During the past more than 20 years, a dramatic development in imaging techniques, especially within CT, emerged. These new imaging techniques require intensive post-processing, e.g. MPR reconstruction and measures, apart from the imaging modality which need to be integrated into the image workflow and the PACS implementation. Along with these new imaging techniques new clinical applications, e.g. peripheral bronchogenic carcinoma detection, and research applications, e.g. study of enhancement pattern of peripheral bronchogenic carcinoma, require changes to the traditional PACS concept. With the development of technology, it is convenient to reconstruct MPR and investigate enhancement pattern of peripheral bronchogenic carcinoma on a PACS workstation [10]. Workstations and electronic display devices in a picture archiving and communication system (PACS) provide a efficient and convenient platform for medical diagnosis. The performance of display devices has to be verified to ensure that image quality is not degraded. In the high background patterns of randomized object test patterns (ROTPs), the sensitivity performance was comparable between both monitors in terms of contrast and resolution, whereas, in the low background patterns, the performance of the commercial color LCD was significantly poorer than that of the diagnostic monochrome LCD in all aspects [11]. In order to ensure that image quality is not degraded, we used PACS and CT workstations with a 5 megapixel (MP) liquid crystal displays (LCDs) in the study.

In order to obtain more information about hemodynamics of bronchogenic carcinoma with lower radiation doses, there scans (one precontrast scan and two postcontrast spiral CT scans) were performed instead of more scans in our study. The study results of Li *et al* revealed most bronchogenic carcinoma showed enhancement at 25 s and maximal enhancement at 90 s [12–13]. So, we performed the first phase scan beginning at 25 s after injection of contrast medium and performed the second phase scan beginning at 90 s after injection of contrast medium. Our results showed that there were not statistically significant difference in precontrast attenuation, the attenuation at 25 s and the attenuation at 90 s of peripheral bronchogenic carcinoma between those measured on a PACS workstation and those on a CT workstation. There was not statistically significant difference in the peak height of peripheral bronchogenic carcinoma between that measured on a PACS workstation and that on a CT workstation. The 62 cases with peripheral bronchogenic carcinoma showed the same enhancement patterns on PACS workstation and CT workstation. The enhancement pattern revealed on a PACS workstation was consistent with feature of peripheral bronchogenic carcinoma. The results showed that efficiency and effectiveness of PACS workstation is as same as those of CT workstation in detecting enhancement pattern of peripheral bronchogenic carcinoma.

Our preliminary study revealed that enhancement pattern of peripheral bronchogenic carcinoma could be

evaluated exactly on PACS workstation. We believe that PACS workstation will play more and more important role in practice of modern medical radiology.

Conflicts of interest

The authors indicated no potential conflicts of interest.

References

1. Li SJ, Zhao Y, Zhu Y, *et al*. Preliminary assessing no-surgical treatment response in bronchogenic carcinoma with double-phase contrast material-enhanced computed tomography. Chinese-German J Clin Oncol, 2009, 8: 152–155.
2. Jemal A, Siegel R, Ward E, *et al.* Cancer statistics, 2006. CA Cancer J Clin, 2006, 56: 106–130.
3. Li SJ, Li CC, Wang X, *et al*. Malignant solitary pulmonary nodules: optimal slice thickness of CT in revealing lobulation. Chin Med Equip J (Chinese), 2012, 33: 64–66.
4. Li SJ, Xiao XS, Liu SY, *et al*. The inhomogeneous perfusion of the solitary pulmonary nodules. Chin J Radiol (Chinese), 2008, 42: 862–865.
5. Li SJ, Zhu F, Liu DB. Preliminary study of enhancement pattern changes in the assessment of nonsurgical treatment in bronchogenic carcinoma. J Clin Radiol (Chinese), 2010, 29: 1336–1339.
6. Li SJ, Xiao XS, Liu SY, *et al*. The clinical value of volume perfusion imaging with dynamic CT in the solitary pulmonary nodules. J Clin Radiol (Chinese), 2008, 29: 1220–1224.
7. Yan WM, Feng WH, Xu WJ, *et al.* PACS/RIS application advantage during optimizing workflow of radiology department. J Med Imaging (Chinese), 2010, 20: 1709–1712.
8. Li SJ, Li CC, Zhu F, *et al*. Preliminary assessing no-surgical treatment response in bronchogenic carcinoma with changes in enhancement pattern. Chinese-German J Clin Oncol, 2012, 11: 508–512.
9. Iagaru A, Gambhir SS. Imaging tumor angiogenesis: the road to clinical utility. AJR Am J Roentgenol, 2013, 201: W183–W191.
10. Ma J, Chen CS, Blute T, *et al.* Antiangiogenesis enhances intratumoral drug retention. Cancer Res, 2011, 71: 2675–2685.
11. Wu J, Wu TH, Han RP, *et al.* Comparison of the commercial color LCD and the medical monochrome LCD using randomized object test patterns. PLoS One, 2012, 7: e37769.
12. Li SJ, Xiao XS, Liu SY, *et al*. Blood flow patterns of solitary pulmonary nodules with enhancement: clinical value of multi-slice spiral CT. Chin J Radiol (Chinese), 2004, 38: 1062–1068.
13. Li SJ, Xiao XS, Liu SY, *et al.* Preliminary study on the dynamic enhanced multi-slice spiral CT in the evaluation of blood flow patterns of malignant solitary pulmonary nodules. Chin J Lung Cancer (Chinese), 2003, 6: 18–21.

DOI 10.1007/s10330-314-0004-x
Cite this article as: Lv CL, Li SJ, Li CC, *et al*. Peripheral bronchogenic carcinoma: Enhancement pattern evaluation on PACS and CT workstation. Chinese-German J Clin Oncol, 2014, 13: 567–571.