Clinical Radiology 71 (2016) 1132–1136

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Solitary lung cavities: CT findings in malignant and non-malignant disease

C.S. Nin [a], V.V.S. de Souza [a], G.R.T. Alves [b,*], R.H. do Amaral [a], K.L. Irion [c], E. Marchiori [b], B. Hochhegger [b]

[a] Federal University of Health Sciences of Porto Alegre, Brazil
[b] Post-graduation Program in Medicine (Radiology), Federal University of Rio de Janeiro, Brazil
[c] Radiology Department Liverpool Heart and Chest Hospital, UK

ARTICLE INFORMATION

Article history:
Received 13 July 2015
Received in revised form
6 April 2016
Accepted 8 April 2016

AIM: To assess the computed tomography (CT) findings of solitary cavitary lesions which could potentially aid in differentiating malignant from non-malignant lung disease.

MATERIALS AND METHODS: A retrospective study of patients diagnosed with a solitary lung cavity at two university hospitals, who underwent multidetector CT examinations of the chest between 2012 and 2014, was performed. Lesions were evaluated for maximum diameter, maximum wall thickness, and associated findings. Statistical analyses were then conducted and a receiver operating characteristic (ROC) curve was calculated to select the most accurate cut-off value for malignant and non-malignant lesions.

RESULTS: CT and clinical records from 96 patients were reviewed. The most frequent aetiologies of non-malignant and malignant lung cavities were mycobacterial infection sequelae (50%, 33/66) and primary lung carcinoma (94%, 28/30), respectively. Significant differences ($p<0.05$) were found between malignant and non-malignant cases when comparing the averages of maximum wall thickness (15.2 and 7.8 mm, respectively) and maximum diameter of lesions (51 and 35 mm, respectively). The presence of either perilesional consolidation or centrilobular nodules favoured the diagnosis of non-malignant conditions ($p<0.05$). Maximum wall thicknesses thresholds of $\leq$7 or $\geq$24 mm were the most accurate in suggesting non-malignant and malignant aetiologies, respectively.

CONCLUSION: Malignant and non-malignant solitary lung cavities differ significantly at CT. Non-malignant lesions tend to exhibit thinner walls, but more perilesional consolidation and centrilobular nodules than malignant lesions. The results reveal that maximum wall thicknesses of $\leq$7 and $\geq$24 mm are indicative of non-malignant and malignant disease, respectively.

Introduction

A cavity is a gas-filled space that appears on imaging examinations as an area of lucency or low attenuation. Pulmonary cavities can occur within areas of pulmonary consolidation, masses, or nodules, and usually result from the drainage of necrotic lesions via the bronchial tree.[1]

* Guarantor and correspondent: G.R.T. Alves, Federal University of Rio de Janeiro, Post-graduation Program in Medicine (Radiology), Professor Rodolpho Paulo Rocco Street, 255, Rio de Janeiro, 21941-913, Brazil. Tel.: +55 55 97291990.
E-mail address: grtalves@gmail.com (G.R.T. Alves).

http://dx.doi.org/10.1016/j.crad.2016.04.009
0009-9260/

Although large, thick-walled lesions can be identified in simple chest radiography (CXR) examinations, a number of smaller cavities (or those with thinner walls) may remain unnoticed until a more accurate radiological assessment is performed. Similarly, the wide range of possible aetiologies for solitary lung cavities detected at CXR often prompts the need for further imaging investigation.

Multidetector computed tomography (CT) of the chest is the current technique of choice for evaluating lung cavities, as it provides precise information on size, shape, location of lesions, and other characteristics that may not be evident on CXRs.[2,3] Based on such features, in combination with an appropriate clinical and laboratory background, radiologists are able to narrow the list of possible diagnoses, such as lung cancer, mycobacterial infection, or even rarer conditions (e.g., pulmonary mycoses and vasculitides)[1–5]; however, few data exist regarding an objective assessment of cavitary lesions at thoracic CT.

The aim of the present study was to determine the most accurate CT findings of solitary lung cavities that would help differentiate malignant from non-malignant conditions.

Materials and methods

Patients

Using the picture archiving and communication systems (PACSs, PixViwer; Pixeon, Florianópolis, Brazil) of two university hospitals located in Brazil's southernmost state (Rio Grande do Sul), patients with cavitary lung lesions who had undergone thoracic CT between June 2012 and April 2014 were identified retrospectively. The searched was initially performed using the terms "cavity" and "cavitary lesion" in the report text field. A third-year radiology resident subsequently confirmed the presence of a solitary lung cavity within the examinations and recorded the demographical data. The local ethics review board approved this study, and it is registered under the reference ISCMPA-25152713.0.0000.5335. Due to its retrospective and anonymised nature, informed consent forms were waived.

Additional information regarding patient data, such as laboratory results, histological reports, and immune status, were retrieved from the electronic medical records (Philips Tasy; Wheb Sistemas, Blumenau, Brazil). The criteria for immunosuppression included corticotherapy or chemotherapy regimens within 4 weeks preceding CT, any history of organ transplant, and patients diagnosed with acquired immunodeficiency syndrome (AIDS). Definitive diagnoses were achieved by histological study, bacilloscopy, or clinical and radiological follow-up. A diagnosis of tuberculosis was made when patients presented with suggestive symptoms, demonstrated response to treatment, and had cultures from respiratory secretions that were positive for *Mycobacterium tuberculosis* and/or histology of the cavity indicated this diagnosis. Lung abscesses were defined by the presence of a compatible clinical history and resolution of both clinical and radiological findings after antimicrobial therapy, and/or postoperative histological analysis. The diagnosis of sequelae from previous mycobacterial infections was established when (1) records of pharmacological treatment completion were present; (2) patients remained asymptomatic for at least 2 years after therapy; and (3) at least two negative results for *M. tuberculosis* culture were demonstrated.

CT assessment and parameters

All examinations were performed using two 64-multidetector CT systems (LightSpeed VCT; GE Healthcare, Milwaukee, WI, USA). The acquisition protocol was: 0.625 mm section collimation, 0.625 mm reconstruction, 0.4 second gantry rotation, 7.5 mm/s table speed, 120 kV tube voltage, 200 mA tube current, and a 40–50-cm field of view.

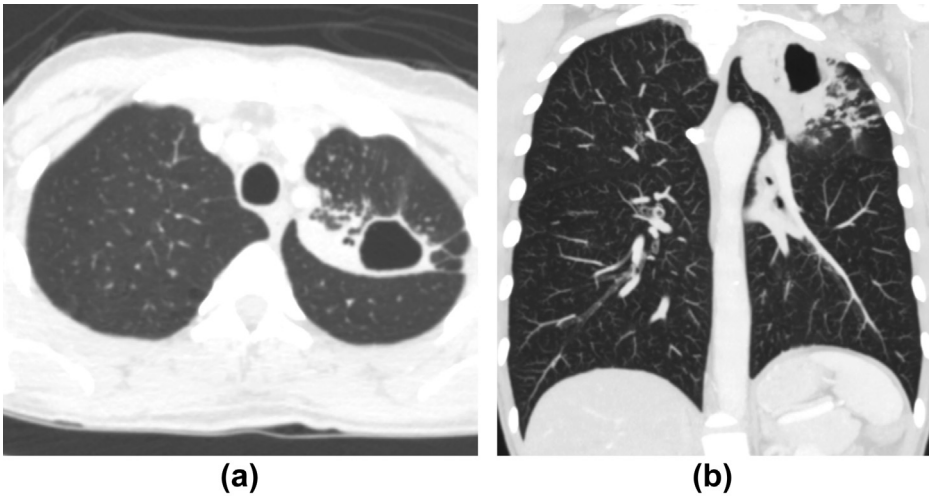

Figure 1 A 50-year-old man with active tuberculosis. (a) Axial CT image demonstrates a thin-walled cavitary lesion in the left upper lobe of the lung. (b) Coronal CT reformatted image evidences perilesional centrilobular nodules. The culture from bronchoalveolar lavage was positive for *M. tuberculosis*.

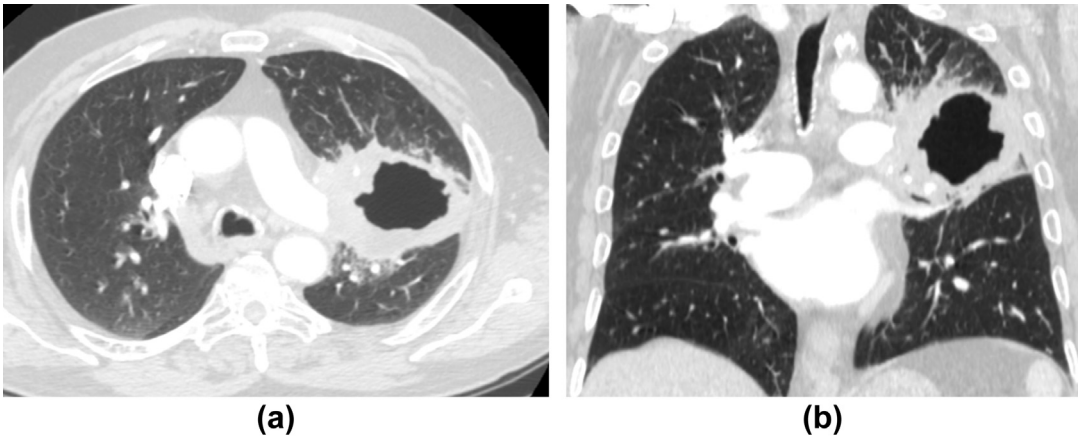

Figure 2 A 75-year-old man with primary lung cancer. (a) Axial CT image reveals a thick-walled cavitary lesion in the left upper lobe of the lung. (b) Coronal CT reformatted image demonstrates the absence of perilesional findings. Histological analysis following lung biopsy confirmed the diagnosis of squamous cell carcinoma.

Two thoracic radiologists, with 5 and 8 years of experience in chest imaging, reviewed the scans consensually using the same workstation (Advantage Workstation 4.4; GE Healthcare). Disagreements between readers were presented to a senior radiologist with more than 20 years of experience in thoracic imaging, who provided the final answer. The radiologists were blinded to both clinical and histological information. For each examination, lesion size (maximum diameter), maximum wall thickness of the cavity (both measured on axial images), and associated findings, regardless of their location or extent, were noted.

Table 1
Patient, lesion, and diagnostic characteristics (n=96).

Patient characteristics	
Sex (male)	59 (61)
Age (years)	55±17
Immunosuppressed	20 (21)
Lesion characteristics	
Wall thickness (mm)[a]	10.1±6.7
Malignant	15.2±7.4
Non-malignant	7.8±4.8
Diameter (mm)[a]	40±23
Malignant	51±28
Non-malignant	35±21
Diagnostic characteristics	
Malignant	30 (31)
Primary	28 (94)
Metastasis	2 (6)
Non-malignant	66 (69)
Mycobacterial infection sequelae	33 (50)
Active pulmonary tuberculosis	24 (36)
Abscess	8 (12)
Aspergillosis	1 (2)
Diagnostic confirmation	
Malignant	30 (31)
Histological	30 (100)
Non-malignant	66 (69)
Histological	30 (45)
Clinical/radiological	15 (23)
Bacilloscopy	21 (32)

Data are presented as $n \pm$ standard deviation (SD) or n (%).
[a] $p<0.05$ (malignant versus non-malignant).

Images were volumetrically acquired and evaluated on both pulmonary and mediastinal windows, using high-resolution and soft kernels, respectively. Measurements were further performed in the axial plane only on a pulmonary window, as the aim was to increase the reproducibility of the results and use a readily applicable technique. Consolidation was defined as a homogeneous increase in lung attenuation obscuring the margins of adjacent vessels and airway walls,[1] and centrilobular nodules were considered as nodular opacities occupying the centre of a normal secondary pulmonary lobule, following the recommendations of the Nomenclature Committee of the Fleischner Society.[1]

Statistical analysis

Study data tabulation and subsequent analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 20.0; IBM, Armonk, NY, USA). For comparison purposes, patients were divided into two groups, according to their final diagnosis, in malignant and non-malignant aetiologies of the solitary pulmonary cavities. The variables of the groups were analysed using independent-sample Student's *t*-test, when numerical and normally distributed, and using the Chi-square test when categorical or expressed in proportions. Tests were run bilaterally, assuming significance if $p<0.05$. After preliminary analysis of the results, receiver operating characteristic (ROC) curves were devised to determine the most accurate cut-off points for differentiating malignant and non-malignant lesions by using the maximum wall thickness of cavities.

Results

Images and medical records of 96 patients who were identified with solitary pulmonary cavities at CT were reviewed, with a mean age of 55±17 years (61% male). Sixty-six cavitary lesions were diagnosed as non-malignant

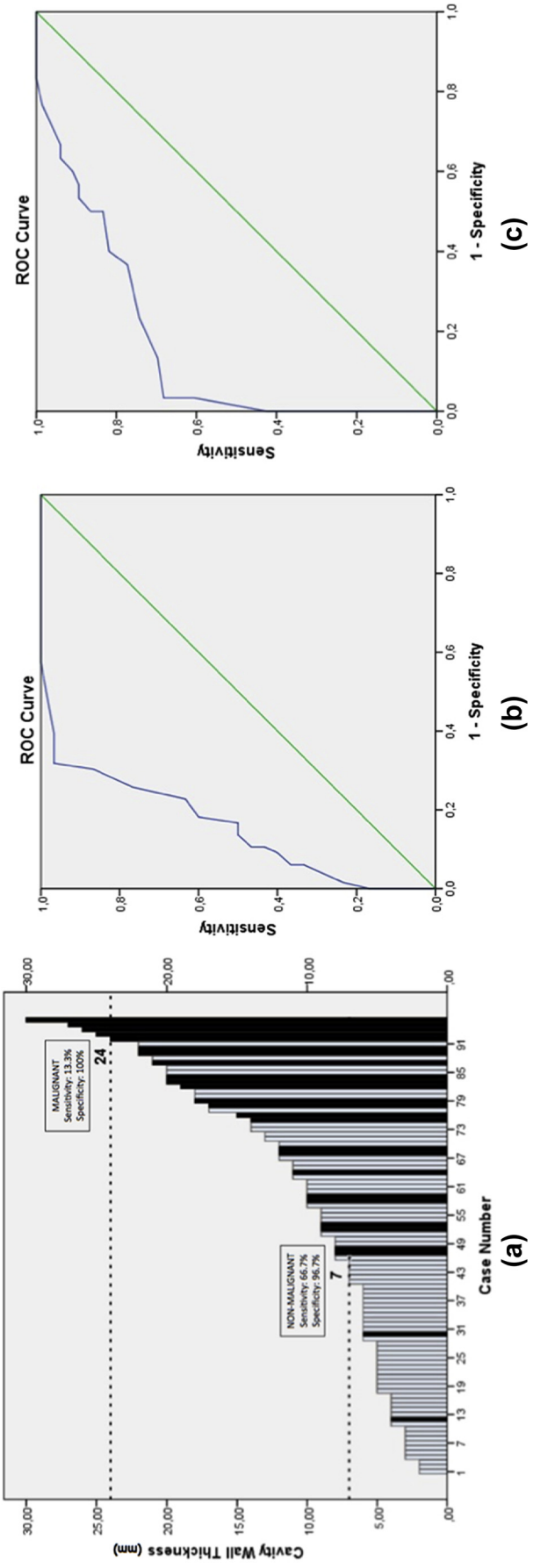

Figure 3 (a) Histogram demonstrating the maximum wall thickness thresholds that best correlate with malignant and non-malignant lesions: 24 mm was considered 100% specific, 13.3% sensitive for malignant aetiologies (b, area under curve, AUC=0.298), whereas 7 mm achieved a specificity of 96.7% and a 66.7% sensitivity (AUC=0.379) for non-malignant lesions (c).

(69%) and 30 (31%) as malignant. Among the non-malignant diagnoses, 33 (50%) consisted of mycobacterial infection sequelae, 24 (36%) of active pulmonary tuberculosis (Fig 1), eight (12%) of lung abscess, and one (2%) of aspergillosis. In the group of malignant aetiologies for solitary lung cavities, 28 (94%) had a final diagnosis of primary lung cancer (Fig 2), and two (6%) were diagnosed as having metastatic disease (Table 1). The immune status did not influence malignancy rates (31% versus 30% prevalence of lung cancers in immunocompetent and immunosuppressed patients, respectively; $p>0.05$) Histological confirmation was obtained in all cases of the malignant group. For non-malignant aetiologies, 30 (45%) were confirmed at histology, 21 (32%) at bacilloscopy, and 15 (23%) using clinical and radiological findings.

Twenty patients (21%) were classified as being immunosuppressed. Among these, 14 were diagnosed with a non-malignant condition (12 with active tuberculosis and two with mycobacterial infection sequelae), and six with malignant conditions (six cases of primary lung cancer). It is noteworthy that the prevalence of active tuberculosis was four-times higher among immunosuppressed than in immunocompetent individuals (60%, 12/20 versus 15%, 12/76; $p<0.05$).

The averages of maximum lesion diameter differed significantly between the malignant and non-malignant groups (51±28 versus 35±21mm; $p<0.05$). The averages of maximum wall thickness in the malignant and benign lesions were also significantly different (15.2±7.4 versus 7.8±4.8mm; $p<0.05$). Fig 3 demonstrates the maximum wall thickness thresholds that best correlated with malignant and non-malignant lesions: 24 mm was considered 100% specific and 13.3% sensitive for malignant aetiologies, whereas 7 mm achieved a specificity of 96.7% and a sensitivity of 66.7% for non-malignant lesions.

Among the associated findings, perilesional centrilobular nodules were seen on the CT images in 27 cases, all of which had a non-malignant aetiology ($p<0.05$). Perilesional consolidations were present in 42 cases, 31 (74%) of which were benign lesions (Table 2, $p<0.05$). No other associated features were found to be statistically significant.

Discussion

Pulmonary cavities are often encountered in chest imaging examinations, and their differential diagnosis

Table 2
Associated CT findings in patients with solitary lung cavities.

Associated findings	
Perilesional centrilobular nodules[a]	n=27
Malignant	0 (0)
Non-malignant	27 (100)
Perilesional consolidation[a]	n=42
Malignant	11 (26)
Non-malignant	31 (74)

Data are presented as n (%).
[a] $p<0.05$ (malignant versus non-malignant).

includes diverse malignant and non-malignant diseases, caused by multiple processes of acquired or congenital origin.[6,7] Various pathogenic mechanisms underlie the formation of cavitary lesions: inadequate local blood supply creating central necrosis, infarction from occlusion of regional nutritional vessels, and blockage of a bronchus resulting in necrosis distal to the obstruction.[8,9]

Many reports have suggested that primary lung abscess, bronchogenic carcinoma, and post-primary tuberculosis are the most common causes of lung cavitation, followed by metastatic tumours, fungal disease, lymphoma, rheumatoid nodules, and granulomatous vasculitides.[9,10] In adults, the two main causes of cavitary pulmonary lesions are malignancy and infection. In the present cohort, possibly because of geographical and epidemiological aspects, tuberculosis-related lesions were the most prevalent (33 residual and 24 cases of active disease).[12]

Different clinical and radiological parameters may be helpful in assessing solitary pulmonary cavities, such as the duration of symptoms, the lesion's inner aspect (smooth or irregular), and its location. When addressed individually, a considerable overlap between malignant and non-malignant aetiologies tends to occur. Previous authors have described that a combination of solitary cavities with thicker walls and irregular inner contours favoured the diagnosis of primary or metastatic lung cancer.[8–11] Woodring *et al.*[4,5] reported that most nodules with a maximum wall thickness >15 mm on CXRs are likely to be malignant in nature, whereas most of those with a maximum wall thickness of ≤4 mm indicate a benign condition. Similarly, other authors had suggested the cut-off points of 15 and 3 mm, respectively.[3] Although other studies have conducted similar investigations on CT series of patients that exhibited pulmonary cavities,[9,10] there is still a lack of defined CT thresholds that effectively aid the evaluation of such lesions at CT. Although the majority of solitary cavities still undergo additional testing (i.e., histological or laboratory sampling), comprehensive CT characterization would avoid unnecessary investigations on benign lesions, as well as eliciting more robust interventions in suspicious lesions.

The results of the present study indicate that maximum wall thickness is among the best criteria for differentiating malignant and non-malignant causes of solitary pulmonary cavities, and that the most reliable limits are 24 and 7 mm, respectively. Not surprisingly, these values contrast with previous thresholds, mainly because of the better spatial resolution and post-acquisition tools provided by CT. The presence of perilesional centrilobular nodules and perilesional consolidations were found to support this differentiation. Although similar descriptions have not been reported thus far, this finding is secondary to the predominantly infective nature of the non-malignant aetiologies of the solitary lung cavities.

Some limitations of the present study should be noted. First, its retrospective nature prevents the authors from correcting occasional inaccuracies in the databases. Second, the relatively small sample rendered the performance of an analysis of covariance and other desirable statistical tests unfeasible. Third, data were obtained from two tertiary-care centres, in which the populations are likely to differ from the general population in some aspects (e.g., prevalence of immunosuppression etc.).

In summary, chest CT imaging is a valuable tool for the characterization of solitary lung cavities. The maximum wall thickness and the presence of centrilobular nodules or perilesional consolidations are the best criteria in distinguishing malignant and non-malignant underlying conditions. At CT, the most appropriate cut-off values that indicate malignancy and benignity are ≥24 and ≤7 mm, respectively.

References

1. Hansell DM, Bankier AA, MacMahon H, *et al*. Fleischner Society: glossary of terms for thoracic imaging. *Radiology* 2008;**246**:697–722.
2. Gadkowski LB, Stout JE. Cavitary pulmonary disease. *Clin Microbiol Rev* 2008;**21**:305–33.
3. Ryu JH, Swensen SJ. Cystic and cavitary lung diseases: focal and diffuse. *Mayo Clin Proc* 2003;**78**:744–52.
4. Woodring JH, Fried AM, Chuang VP, *et al*. Solitary cavities of the lung: diagnostic implications of cavity wall thickness. *AJR Am J Roentgenol* 1980;**135**:1269–71.
5. Woodring JH, Fried AM. Significance of wall thickness in solitary cavities of the lung: a follow-up study. *AJR Am J Roentgenol* 1983;**140**:473–4.
6. Kim NR, Han J. Pathologic review of cystic and cavitary lung diseases. *Korean J Pathol* 2012;**46**:407–14.
7. Erasmus JJ, Connolly JE, McAdams HP, *et al*. Solitary pulmonary nodules: part I. Morphologic evaluation for differentiation of benign and malignant lesions. *RadioGraphics* 2000;**20**:43–58.
8. Gurney JW. Determining the likelihood of malignancy in solitary pulmonary nodules with Bayesian analysis. *Radiology* 1993;**186**:405–13.
9. Vourtsi A, Gouliamos A, Moulopoulos L, *et al*. CT appearance of solitary and multiple cystic and cavitary lung lesions. *Eur Radiol* 2001;**11**:612–22.
10. Li B-G, Ma D-Q, Xian Z-Y, *et al*. The value of multislice spiral CT features of cavitary walls in differentiating between peripheral lung cancer cavities and single pulmonary tuberculous thick-walled cavities. *Br J Radiol* 2012;**85**:147–52.
11. Yang Y-W, Kang YA, Lee SH, *et al*. Aetiologies and predictors of pulmonary cavities in South Korea. *Int J Tuberc Lung Dis* 2007;**11**:457–62.
12. Conde MB, Melo FA, Marques AM, *et al*. III Brazilian Thoracic Association Guidelines on tuberculosis. *J Bras Pneumol* 2009;**35**:1018–48.