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Incidental lung nodules on CT examinations of the abdomen: Prevalence and reporting rates in the PACS era

Maria Francesca Rinaldi [a], Tommaso Bartalena [a,*], Giovanni Giannelli [a], Giovanni Rinaldi [a], Nicola Sverzellati [b], Romeo Canini [c], Giampaolo Gavelli [d]

[a] Radiologia III - Azienda Ospedaliera Pol. S.Orsola-Malpighi, via Massarenti 9 - 40138 Bologna, Italy
[b] Dipartimento di Scienze Cliniche, sezione di Radiologia - Università di Parma, via Gramsci 14 - 43100 Parma, Italy
[c] Dipartimento Clinico di Scienze Radiologiche ed Istocitopatologiche, divisione di Diagnostica per Immagini – Università di Bologna, via Massarenti 9 - 40138 Bologna, Italy
[d] Servizio di Diagnostica per Immagini, Istituto Scientifico Romagnolo per lo Studio e la Cura dei Tumori (I.R.S.T.), via Piero Maroncelli, 40 - 47014 Meldola (FC), Italy

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ABSTRACT

Objectives: To retrospectively evaluate prevalence, reporting rates and clinical implications of incidental pulmonary nodules detected in multidetector computed tomography (MDCT) abdominal studies.
Materials and methods: Abdominal MDCT studies of 243 consecutive patients, 94 of whom had a history of cancer, were evaluated. Lung bases included in the scan were reviewed on a PACS workstation with different window settings and post-processing techniques. Nodules were classified according to their density (calcified, solid noncalcified, non-solid, part-solid) and size (<4 mm; 4–6 mm; 6–8 mm; >8 mm). The study findings were compared with the corresponding radiologic reports. Previous of following CT studies, when available from the PACS, were also reviewed to evaluate changes in number and size of the detected nodules.
Results: An average of 8.2 cm of lung parenchyma was imaged in each patient. 213 noncalcified nodules (NCNs) were identified in 95 patients (39.1%) but only 8 patients (8.4%) had it mentioned in the final report. Comparison CT studies were available for 44 out of the 95 positive patients showing disappearance of the nodules in 2 cases, no interval change in 26 and progression in size and/or number in 16 patients, in whom a final diagnosis of metastasis or primary lung cancers was achieved.
Conclusion: Radiologists tend to overlook lung portions on abdominal CT studies. Underreporting may affect patient care and have medico-legal implications since images are permanently stored in digital format on PACS and CD-ROMs. Management of the discovered nodules should be tailored to the clinical situation of the patient, and particular care should be reserved to patients with oncologic history.

1. Introduction

A consistent portion of lung parenchyma is always included in abdominal CT studies. In the pre-PACS era, hard-copy documentation of lung bases with proper window settings was not routinely performed in many centers because of filming cost.

Actually, such information does not get lost thanks to permanent digital storing provided by PACS. Lung nodules identified by CT examinations of the abdomen may have an important effect on the management of the patients. Herein, we sought to determine the prevalence, the reporting rate and the clinical significance of the nodules at the lung bases covered by abdominal CT examinations. To the best of our knowledge this is the first study to address this topic.

* Corresponding author. Tel.: +39 0516364740; fax: +39 051349797.
E-mail address: t.bartalena@email.it (T. Bartalena).

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2. Materials and methods

All abdominal MDCT studies performed between 1 January and 1 March 2007 at our radiology department were retrospectively reviewed from the hospital's PACS archive.

The institutional review board did not require the patients' approval or informed consent for the retrospective review of their records and images. A total of 243 consecutive patients (113 males, 130 females) with a mean age of 62.6 years (range 7 – 95) represented our study cohort. CT examinations were performed for different queries: oncologic staging and follow-up (94/243; 38.7%), CT-angiography (45/243; 18.5%), post-surgical and intensive care unit controls (36/243; 14.8%), CT-urography (27/243; 11.1%), interventional CT-guided procedures (22/243; 9.1%), virtual colonoscopy (19/243; 7.8%). All CT studies were performed on a 16-row CT scanner (Somatom Sensation Cardiac 16, Siemens, Forchheim, Germany). Images were retrieved on a diagnostic PACS workstation (Kodak Carestream PACS Client Suite version 10.1 sp1, Rochester, NY, USA) and independently evaluated by 2 radiologist not involved in the initial interpretation of the exam (TB, GGi). Thin section datasets (2 mm thickness slice with 1 mm increment) were available for each study and were reviewed with either a mediastinal (center 60 H; width 360 H) and a lung (center -600 H; width 1800 H) window setting.

Multiplanar reformations (MPR) and maximum intensity projections (MIP) reconstructions were also used to improve nodules' detection. Nodules' maximum diameter was determined using electronic calipers on the axial images. Nodules were classified according to size in the following categories: below 4 mm; between 4 and 6 mm; between 6 and 8 mm; over 8 mm). The weighted kappa coefficient of agreement (K_w) used to calculate the interobserver variation for the size scores. Interobserver disagreements were resolved by consensus review of divergent scores.

Nodules were also classified according to their density as following: calcified, solid noncalcified, non-solid, part-solid.

Nodules are defined calcified when they have attenuation values similar to bone on mediastinal window settings. Solid noncalcified nodules instead have soft tissue density that effaces the contour of vessels with which they are in contact.

Non-solid nodules have lower density than vessels and appear as focal ground glass areas that doesn't efface the outline of vessels in contact with or traversing such lesions. Part-solid nodules, have either a non-solid ground glass component or a solid soft tissue density component.

Medical records of the patients were reviewed to see oncologic history.

Official radiology reports of the patients with nodules were retrospectively reviewed from the hospital RIS (radiology information system) and whether the nodules had been reported or not was noted. Previous or following CT studies of the patients with NCNs were retrieved from the hospital PACS archive which comprises examinations performed from its installations in our hospital (January 2006) to date and includes studies performed with the CT scanner of our department and from other radiology departments of the hospital employing 2 different CT scanners (LightSpeed 16, GE Healthcare Milwaukee, WI, USA; Somatom Emotion 6, Siemens, Forchheim, Germany). Only complete chest CT studies or abdominal CT studies with the same lung bases coverage as in the baseline exams were considered eligible for comparison. Evolution of the nodules was assessed according to the nodules' size changes: (1) resolution (nodule was no longer present), (2) stability (dimensional growth < 1.73 mm) and (3) progression (dimensional growth > 1.73 mm). Changes in lung nodules number were also recorded.

3. Results

An average of 8.2 cm (range 5.1–11.4 cm) of lung parenchyma was scanned in every patient. Pleural effusion and atelectasis were present in 35 patients (14.4%) limiting the evaluation of lung parenchyma. 137 patients (56.3%) had no pulmonary nodules. The remaining 106 patients had 248 nodules (average number of nodules per patient 2.33; range 1–26), 35 of those were calcified nodules, 211 solid noncalcified, 1 part-solid and 1 ground-glass nodule. 11 patients displayed only calcified nodules (total 13 nodules), 13 patients demonstrated both calcified and noncalcified nodules and 82 patients had only noncalcified nodules. (Table 1)

A total of 213 NCNs were found in 95 patients (39.1%) with a mean of 2.2 nodules per patient. 50 subjects had a single NCN, while 45 had multiple NCNs (range 2–18).

Size classification of NCNs showed prevalence of very small pulmonary nodules with 157 nodules below 4 mm (73.7%), 36 in the 4–6 mm range (16.9%), 6 in the 6-8 mm range (2.8%) and 14 nodules measuring more than 8 mm (6.6%). (Table 2) There was a good (K_w = 0.732) interobserver agreement in the evaluation of the nodule size categories. In 46 out of 213 NCNs (21.6%), a final decision was obtained by consensus because the observers' evaluation was discordant for the nodule size classification.

NCNs were detected in 52 out of 149 non-oncologic patients (34.9%) and in 43 out of 94 oncologic patients (45.7%). (Table 1) Only 8 of the 95 patients (8.4%) with NCNs had it reported by the interpreting radiologist whereas in the remaining 87 patients (91.6%) were unmentioned. 51 patients with NCNs had no comparison studies. Previous or following CT studies of the chest and/or abdomen were available for comparison for 44 patients (28 of those were oncologic) with a mean time interval of 10.2 months (range 2–22).

Of those 29 were performed on the same scanner used in baseline studies, whilst the remaining 15 comparison studies were performed on different CT scanners. Thin section datasets were available for each exam; slice thickness was 2 mm for exams on the Siemens 16-MDCT and on the GE 16-MDCT and 2.5 mm on the Siemens 6-MDCT. Scanning protocols and other image reconstruction parameters (kV, mAs, convolution kernel, use of contrast media) varied quite often among baseline and follow-up studies.

Review of the available CT studies showed no interval change in 26 patients, disappearance of the nodules in 2 patients, increase in size and/or number of the nodules in 16 patients. In the latter subgroup the interpreting radiologists had reported the nodules in only 4 patients (25%) on the initial abdominal CT study. There was no interobserver variability regarding the evolution of the nodules. A final diagnosis of 4 primitive lung cancers (2 in patients with no known previous history of cancer and 2 in oncologic patients) and 12 cases of metastatic lung disease (all in patients with previous oncologic history) was obtained. (Figs. 1–3)

Primary lung cancers had a mean diameter of 7.5 mm (range 5–9.5 mm) at presentation and of 11.7 mm (range 9.2–13.3 mm) after a mean follow-up period of 12 months (range 9–14). In all cases the lesions appeared as peripheral rounded NCNs at baseline

Table 1
Number of patients with and without nodules. Distribution of nodules in the patients of the study population according to nodule type and oncologic history. (CNs = calcified nodules; NCNs = noncalcified nodules).

Type of nodule			
No. nodules	CNs only	Either CNs or NCNs	NCNs only
137 (56.3%)	11 (4.5%)	13 (5.3%)	82 (33.7%)
Oncologic history			
NCNs + non-oncologic	NCNs – non-oncologic	NCNs + oncologic	NCNs – oncologic
52 (34.9%)	97 (65.1%)	43 (45.7%)	51 (54.2%)

Table 2
Distribution of pulmonary nodules according to density, size of noncalcified nodules and patients oncologic history. (CNs = calcified nodules; NCNs = noncalcified nodules).

Nodule density	CNs	Solid NCNs	Part-solid	Ground-glass	Total
Non-oncologic	20 (16.1%)	103 (83.1%)	0	1 (0.8%)	124
Oncologic	15 (12.1%)	108 (87.1%)	1 (0.8%)	0	124
All	35 (14.1%)	211 (85.1%)	1 (0.4%)	1 (0.4%)	248
NCNs size	<4 mm	4–6 mm	6–8 mm	>8 mm	Total
Non-oncologic	89 (85.5%)	13 (12.5%)	1 (1%)	1 (1%)	104
Oncologic	68 (62.3%)	23 (21.1%)	5 (4.6%)	13 (11.9%)	109
All	157 (73.7%)	36 (16.9%)	6 (2.8%)	14 (6.6%)	213

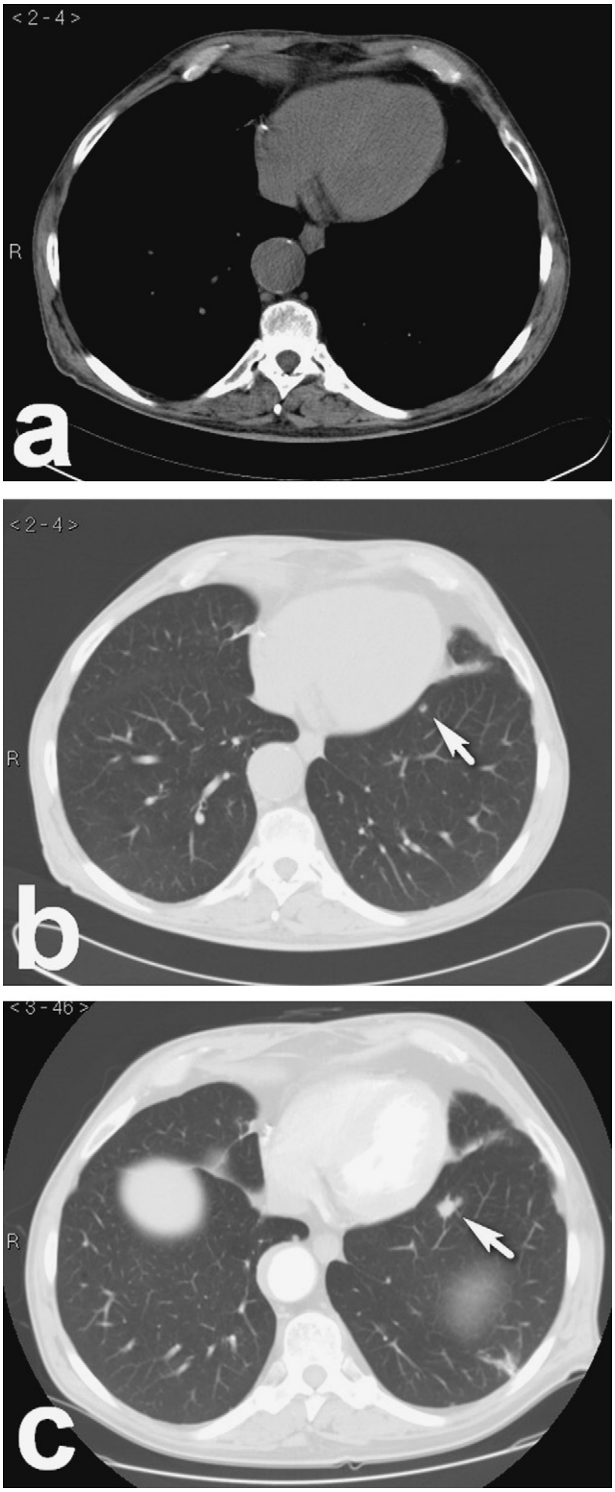

Fig. 1. Abdominal CT scan of a 61 years old male heavy smoker with no previous oncologic history studied for an abdominal aorta aneurysm. (a, b) Small NCN in the lower lingula which is visible only with lung windows settings. (c) 9 months follow-up CT scan shows increase in size of the nodule. The patient underwent surgery and a stage I adenocarcinoma was resected.

whilst 3 showed irregular spiculated margins and 1 had lobulated contour at follow-up.

Patients with metastatic disease had 69 nodules at baseline with a mean of 5.75 nodules per patient (range 2–11) and an average nodule diameter of 4.8 mm (range 2–10.2 mm). The number of nodules increased more than four-fold at follow-up and the maximum nodule diameter was 24 mm.

4. Discussion

The term "PACS" was coined during the First International Conference and Workshop on Picture Archiving and Communication Systems held in Newport Beach in 1982. PACS consists of image acquisition devices, storage archiving units, display workstations, computer processors, and databases, integrated by a communications network and data management system [1]. Since its introduction a progressive transaction to a film-bases environment to filmless digital storage has taken place. PACS yields potentially more information for review since no image is discarded or cropped and can be further manipulated and post-processed in any moment at the workstation during diagnostic interpretation by means of a few mouse clicks [2]. In particular the use of multiple window and level settings during soft-copy interpretation results in improved lesion detectability and characterization with greater diagnostic efficacy [3] without compromising efficiency. In a film-based environment the number of window and level settings that can be used for any CT scan interpretation is limited by filming costs since each image set must be individually printed.

This is particularly true for lung bases scanned during CT examinations of the abdomen. At our institution in the pre-PACS era, hard-copy documentation of lung bases with adequate window settings was not routinely performed; that meant permanent loss of information since digital storing of the DICOM images on the CT scanner console was available just for a limited time and no back-up archive existed.

In the PACS era, the DICOM images are instead stored in the main hospital PACS archive for a long period of time (10 years at our institution) and burned in CD-ROMs which are given to the patient; this means that information about lung parenchyma can be obtained in any moment by simply changing the display window settings with a few mouse clicks.

For these reasons lack of sensitivity in recognizing lung nodules on abdominal CT images can no longer be exclusively justified by technical and/or financial considerations in the PACS era, owing to the possibility to routinely acquire high resolution images and to assess chest CT images filmlessly.

The first objective of our study was to evaluate the prevalence of incidental pulmonary nodules in CT abdominal studies which proved to be quite high (39.1% of our patients had NCNs) despite the limited lung coverage. This data is not surprising since after the introduction of MDCT the detection of very small lung nodules has become routine thanks to thinner collimation with the last generation scanners and NCNs rates as high as 76% have been reported in some case series [4].

Moreover our study revealed a striking discordance between the high number of incidental NCNs and the extremely low reporting rates by interpreting radiologist; we think the main reason to explain it is that radiologists probably did not review at all lung bases with proper window settings. The vast majority of the detected nodules were indeed not visible on abdominal window settings.

Another possible cause for missed pulmonary nodules is that probably lung bases were not visualized using with maximum-intensity-projection (MIP) reconstructions.

This post-processing tool first described by Napel and colleagues [5] consists of projecting the voxel with the highest attenuation value on every view through a stack of preselected axial images onto a 2D image.

This technique is mainly applied in vascular radiology but it can also be used to improve the detection of pulmonary nodules since it enhances reviewer nodule detection and facilitates the diagnosis of pulmonary nodules over single axial images with shorter reporting times [6].

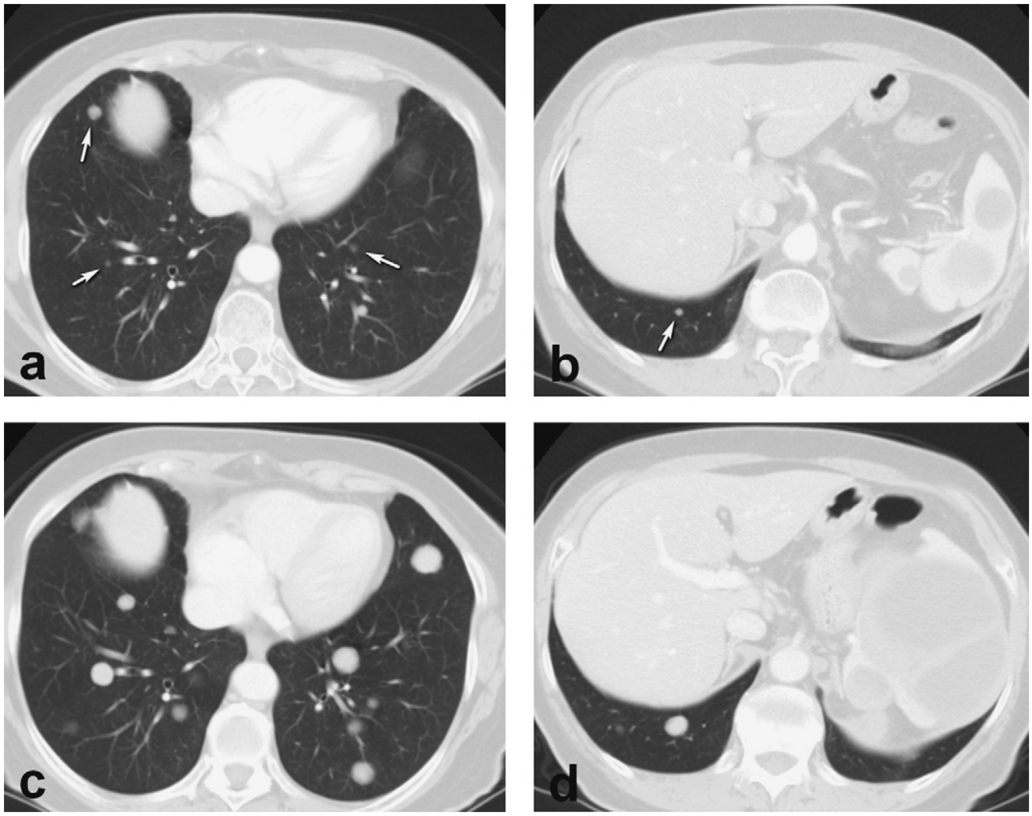

Fig. 2. Abdominal CT scan of a 78 years old female with splenic metastasis by melanoma. (a, b) 4 small NCNs are visible in both lung bases. Only the bigger one was visible with abdominal window settings (images not shown). (c, d) CT scan repeated 3 months later shows disease progression in the spleen and in the lungs with appearance of new metastatic nodules and increase of size of the previous ones.

MIP slabs also eliminate some of the interobserver variability and reduces the effects of reviewer experience in nodule detection [7]. MIP post-processing is now available in many PACS workstations including the one we used in our study (Fig. 3).

Even though a year passed by from PACS installation in our hospital, it seems that radiologists were still not taking full advantage of all its capabilities like multiple window settings reporting and post-processing tools and did not change the way they review abdominal CT studies overlooking incidental lung nodules in the vast majority of the cases.

Another advantage of PACS is that digital storing allows faster retrieval of previous examinations for comparison so the second part of our study focused on clinical implications of these findings and the effect of their underreporting.

Our data show that this behavior lead to missed or delayed diagnosis of important occult pathology in a not negligible number of cases; moreover our result probably underestimates the real incidence of malignancy because we lack comparison studies for a consistent portion of the patients with NCNs.

Radiologists should remember that, unlike in an hard copy environment, these missed findings can be easily traced back on PACS or CD-ROMs and this may have serious medico-legal implications. This means that lung bases must be reviewed as any other structure and incidental nodules should be cited and ade-

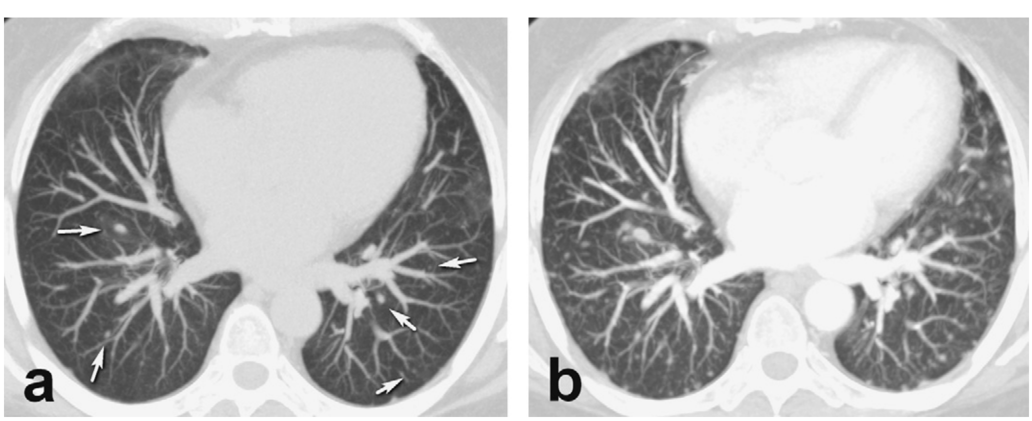

Fig. 3. Abdominal CT scan of a 58 year old man with hepatic cirrhosis and hepatocellular carcinoma (HCC). (a) multiple small NCNs found in both lung bases, not clearly visible with abdominal window settings (images not shown) and much better seen on MIP reconstruction with lung window settings. (b) 4 months follow-up CT scan show dramatic increase in number of nodules representing metastatic HCC.

quate management should be suggested in the final radiologic report.

Other authors have stated before that the vast majority of lung nodules detected at CT scan, especially those of low size, are benign in nature [8] representing intraparenchymal lymphnodes or old granulomatous disease, however a lung cancer in an early stage cannot be ruled out on the basis of its CT appearance and follow-up is necessary to confirm stability.

Factors the influence the likelihood of malignancy of a nodule are its size and density and clinical history of the patient including age, smoking habits and history of previous cancer. In CT-lung-cancer-screening studies of high risk populations, the prevalence of cancer among nodules detected measuring less than 5 mm varies between 0.1% and 1%. The prevalence varies between 1% and 30% for nodules measuring 5–10 mm, and 30–80% for nodules over 10 mm [9].

The new guidelines for follow-up and management of small pulmonary nodules on CT scans in non-oncologic patients [10] propose different follow-up strategies for low-risk and high-risk patients reducing the number and the frequency of follow-up scans for nodules less than 8 mm in both categories. More aggressive follow-up including contrast enhanced CT, PET and/or biopsy is suggested only for nodules bigger than 8 mm.

These guidelines however do not apply to oncologic patients that should be managed differently regardless of their size. Antecedent cancer history is indeed associated to a higher probability of malignancy for pulmonary nodules. It has been estimated that metastases from previous cancer account for almost half of pulmonary nodules seen among oncologic patients [11].

In our study the majority of nodules that showed neoplastic nature were indeed found among oncologic patients and represented metastases in most cases.

Our study has several limitations. As we already mentioned, comparison studies were not available for many of the patients with NCNs. Since the vast majority of nodules was not reported, no follow up exams of such findings were specifically required, moreover we could not review CT scans performed before PACS installation in our hospital.

Visual assessment and limited follow-up interval were probably not sufficient in many cases to establish a definite diagnosis of stability of the nodules.

All nodule measurements were based on electronic calipers; Revel et al. showed that both intra- and interreader agreement for 2D measurement of nodule size on CT scans is suboptimal [12]. Though we did not specifically calculate intra-reader variability since readers did not perform repeated measurements on the same nodule, we found interreader variability in size classification with disagreement in approximatively 1 out 5 nodules. In our study, there was no interobserver variability about the evaluation of the changes of the nodules at follow-up CT examinations by using a 1.73 mm threshold as definite evidence of lesions growth. This value corresponds to the 95% limit of interreader agreement found by Revel's study. All the malignant nodules we found clearly passed that threshold however we could not completely exclude malignancy in some of the nodules which exhibited a lesser growth rate.

Volumetric software analysis has been advocated as the method of choice to assess lung nodules growth to discern between benign and malignant nodules [13].

Unfortunately nodule volumetry software is not implemented in every PACS workstations including ours. Moreover the accuracy and reproducibility of nodules volumes and doubling times calculations would have been affected by the use of different reconstruction parameters [14] and different contrast protocols in the CT scans we reviewed; software-based volume measurements of pulmonary nodules after administration of contrast medium are indeed higher than those of unenhanced scans [15].

5. Conclusions

In conclusion, radiologists should take time to review lung bases on abdominal CT studies taking advantage of PACS capabilities since lung pathology may be incidentally visible in it. Management of the discovered nodules should be tailored to the clinical situation of the patient; Fleischner society's guidelines may be applied to non-oncologic patients whereas stricter follow-up should be reserved to patients with previous history of cancer.

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