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FULL PAPER

Pulmonary computed tomography findings in patients with chronic aspiration detected by videofluoroscopic swallowing study

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Objective: To demonstrate CT findings in patients with chronic aspiration compared with a control group without aspiration, as detected by the videofluoroscopic swallowing study (VFSS).
Methods: This retrospective, observational study included patients with and without diagnoses of aspiration confirmed by VFSS, who underwent CT examination of the lungs between 2010 and 2014. Two radiologists blinded to the presence of aspiration reviewed the images to detect the presence of any abnormality. Consensus was reached with a third radiologist. CT pulmonary findings (bronchial thickening, bronchiolectasis, centrilobular nodules, ground-glass opacities, atelectasis, consolidation and air trapping) were compared between the groups using the χ^2 test, with a significance level of 0.05.
Results: A total of 56 patients (28 patients with diagnoses of aspiration; 52% male, mean age 65 ± 15 years) were included in the study. Patients with aspiration were more likely to than those in the control group to demonstrate atelectasis, centrilobular nodules, bronchiolectasis, consolidation and ground-glass opacities (all $p < 0.05$), with a significant predilection for the lower lobes ($p < 0.001$). Bronchial wall thickening and air trapping did not differ between groups.
Conclusion: Atelectasis, centrilobular nodules, bronchiolectasis, consolidation and ground-glass opacities occurred more frequently in patients with aspiration than in those without aspiration, with a pronounced tendency for distribution in the lower lobes.
Advances in knowledge: CT findings of aspiration are very important, as pulmonary symptoms may be the first manifestation of this disorder. Knowledge of these findings is essential to enable the early diagnosis of aspiration disorders and prevent lung damage.

INTRODUCTION

Swallowing is a dynamic and complex process requiring the co-ordination of various structures, which act in sequence to conduct food from the oral cavity to the stomach. It comprises three phases: oral, pharyngeal and oesophageal.[1,2] Dysphagia, a swallowing disorder, markedly affects individuals' social and psychological relationships and is associated with significant morbidity and mortality.[3] Dysphagia can manifest through a series of signs and symptoms, such as coughing, choking and globus pharyngeus and is a major risk factor for aspiration pneumonia.[4] A study indicated that 5–15% of community-acquired pneumonia cases are aspiration pneumonia. Aspiration pneumonia is the most common cause of death in patients with dysphagia, a condition that affects about 300,000–600,000 people each year in the USA.[5]

Clinicians should be familiar with the different types of aspiration lung disease to enable the correlation of clinical information with main tomographic findings. Diffuse aspiration bronchiolitis is the inflammation of the bronchioles, with symptoms including cough, bronchospasm and dyspnoea. Radiographically, patients with this condition demonstrate unilateral or bilateral tree-in-bud nodularity, centrilobular nodules and areas of increased attenuation. Aspiration pneumonitis, caused by the acute inhalation of gastric contents, appears on CT as airway thickening with ground-glass opacities showing a centrilobular and peribronchovascular distribution. In

contrast, the radiographic manifestations of aspiration pneumonia, which involves the aspiration of the oropharyngeal material (*i.e.* saliva, secretion or food), include segmental or lobar airspace consolidation. The most common aspiration type in children is foreign body aspiration, which may cause post-obstructive atelectasis, air trapping, recurrent pneumonia, bronchial wall thickening and bronchiectasis. Finally, exogenous lipoid pneumonia, caused by the aspiration of lipoid material (mineral, vegetable or animal), shows a predominantly basilar and paramediastinal distribution.[6]

The videofluoroscopic swallowing study (VFSS) is the gold standard for the evaluation of swallowing disorders and should be used specifically to assess aspiration.[7,8] Many patients with oropharyngeal dysphagia have aspirated saliva or food into the lungs, which may cause lung damage.[9,10] Little evidence is available to confirm an association between the location of lung injury and the type of aspiration, and not all previous studies of aspiration pneumonia have confirmed dysphagia using the VFSS.[11,12]

CT findings of aspiration are very important, as pulmonary symptoms may be the first manifestation of this disorder. Knowledge of these findings is essential to enable the early diagnosis of aspiration disorders and prevent lung damage. However, no controlled study has been conducted to identify the most common imaging findings in patients diagnosed with aspiration. Thus, the description of imaging characteristics in patients with aspiration and comparison with findings in those without this condition are needed. The aim of this study was to characterize CT findings in patients with chronic aspiration.

METHODS AND MATERIALS

Patients and study design

All eligible adult patients (aged ≥18 years) who were referred consecutively for VFSS and subsequently underwent chest CT examination for the staging of extrapulmonary malignancy between May 2010 and October 2014, at the department of radiology of terciary care hospital, were enrolled in this study retrospectively. Clinical, imaging and laboratory data were reviewed by the examination of medical records. Aspiration was confirmed by VFSS and was performed by a speech-language pathologist and a radiologist with 5 years' experience. The time interval between the completion of VFSS examination (aspiration status) and CT was up to 2 months. In VFSS barium contrast was used and in CT it was not.

This study followed the recommendations of the Declaration of Helsinki and was approved by the regional bioethics review board. With the exception of aspiration diagnosis, exclusion criteria were: active lung infection (determined by the use of antibiotics, documented fever or abnormal white blood cell count); metastatic neoplasia; lung, oesophageal or gastric cancer diagnosis; lung transplantation, lobectomy or other pulmonary interventions; confirmed immunosuppression (congenital, human immunodeficiency virus or chemotherapy related); and clinical evidence of a diagnosed obstructive or restrictive pulmonary disorder in medical records. Patients with lung, oesophageal or gastric cancer were excluded because these conditions

Table 1. Pulmonary CT findings

VFSS aspiration	No						Yes					
CT findings	LUL	LNG	LLL	RUL	ML	RLL	Total	LUL	LNG	LLL	RUL	ML	RLL	Total
Bronchial thickening	17 (19)	19 (21)	7 (8)	19 (21)	20 (22)	7 (8)	89 (53)	9 (10)	8 (9)	24 (26)	7 (8)	17 (19)	26 (29)	91 (54)
Bronchiolectasis	–	–	–	–	–	–	–	–	–	12 (48)	–	–	13 (52)	25 (15)
Centrilobular nodules	–	–	3 (43)	–	–	4 (57)	7 (4)	–	–	13 (48)	–	–	14 (52)	27 (16)
Ground glass	–	–	–	–	–	–	–	–	–	4 (57)	–	–	3 (43)	7 (4)
Atelectasis	–	–	1 (25)	–	–	3 (75)	4 (2)	–	–	9 (29)	–	4 (13)	18 (58)	31 (18)
Consolidation	–	–	–	–	–	–	–	–	–	5 (50)	–	–	5 (50)	10 (6)
Air trapping	17 (19)	19 (21)	7 (8)	19 (21)	20 (22)	7 (8)	89 (53)	9 (10)	8 (9)	24 (26)	7 (8)	17 (19)	26 (29)	91 (54)
Total	34 (18)	38 (20)	18 (9)	38 (20)	40 (22)	21 (11)	189 (73)	18 (6)	16 (5)	91 (32)	14 (4)	38 (13)	105 (40)	282 (80)

LLL, left lower lobe; LNG, lingular segment; LUL, left upper lobe; ML, middle lobe; RLL, right lower lobe; RUL, right upper lobe; VFSS, videofluoroscopic swallowing study.

can interfere with swallowing. Two radiologists with 5 and 7 years' experience in thoracic radiology, respectively, who were blinded to the presence of aspiration, independently reviewed CT images to identify the presence of any abnormality. Consensus was reached with a third radiologist with 20 years' experience. Interobserver agreement was also examined in this study.

Imaging parameters

VFSSs were performed using a fluoroscopy unit (Axiom Iconos R100; Siemens Medical Systems, Forchheim, Germany) linked to a computerized image-recording system that allowed a detailed analysis of examination results. During the VFSS, patients remained seated and lateral and anteroposterior images were captured, with upper and lower limits ranging from the oral cavity to the stomach. The protocol included functional intake of liquid and foods with pasty and solid consistencies, with liquid barium.

CT images were acquired using two commercially available 64-row multidetector CT scanners (SOMATOM Sensation 64 Systems; Siemens Medical Systems, Forchheim, Germany/ LightSpeed VCT; GE Healthcare, Milwaukee, WI). The examinations were performed in the craniocaudal direction to prevent movement artefacts. The parameters were: collimation, 1 mm; rotation time, 0.33 s; pitch factor, 1.3; dose, 120 kV; and 200 mAs. All CT examinations were performed without contrast. All CT images were reconstructed with axial 1-mm slice thickness. Sagittal and coronal reconstruction with and without maximum intensity projection was also performed. The use of automatic exposure control and soft kernel was allowed, and a data matrix of 512 × 512 matrix size was used. The scanners were calibrated periodically according to the manufacturer recommendations.

Statistical analysis

CT pulmonary findings (bronchial thickening, bronchiolectasis, centrilobular nodules, ground-glass opacities, atelectasis, consolidation, air trapping and the localization of these findings) were compared between the patients with aspiration and the control group.

Excel® software (Microsoft Corporation, Redmond, WA) was used for data tabulation and descriptive analysis. For continuous variables, the mean, median, maximum and minimum values and standard deviations were calculated. For categorical variables, frequencies were expressed as percentages. Correlative analysis was performed with Stata software v.12.1 (StataCorp, College Station, TX). The χ^2 test was applied to categorical (qualitative) variables, which comprised all measurements cross-tested by the authors. Tests were performed bilaterally, with a 0.05 level of significance. These tests were performed separately for each observer. Interobserver agreement was assessed with linearly weighted κ statistics for categorical variables and the Pearson's correlation coefficient for continuous variables. The level of agreement was defined as follows: poor, $\kappa = 0$–0.20; fair, $\kappa = 0.21$–0.40; moderate, $\kappa = 0.41$–0.60; good, $\kappa = 0.61$–0.80; and very good, $\kappa = 0.81$–1.00.[13]

RESULTS

From an initial sample of 1300 patients who had undergone VFSS, 56 patients had undergone chest CT examination for the staging of extrapulmonary cancer. Of these patients, 28 patients showed pulmonary aspiration according to the VFSS and underwent CT within the period of up to 2 months. A total of 56 patients with a mean age of 65 (±15) years and nearly equal sex distribution [29 (52%) males] were included in the analysis. All patients were referred for VFSS because their symptoms included chronic cough.

There are no differences in the cancer diagnosis among the 56 patients: 38 patients had diagnoses of colon cancer, 10 patients had diagnoses of renal cancer, 5 patients were diagnosed with urinary bladder cancer and 3 patients were diagnosed with melanoma. No significant difference in the aspiration diagnosis was observed according to the cancer type. 32 patients (21 patients with and 11 patients without aspiration) were diagnosed with cerebrovascular disease ($p < 0.05$). κ values for interobserver agreement were 0.88 for bronchiolectasis, 0.86 for consolidation, 0.84 for centrilobular nodules, 0.82 for atelectasis, 0.79 for ground-glass opacities, 0.74 for air trapping and 0.54 for bronchial wall thickening.

Figure 1. Comparison between CT findings in patients with and without aspiration. VFSS, videofluoroscopic swallowing study.

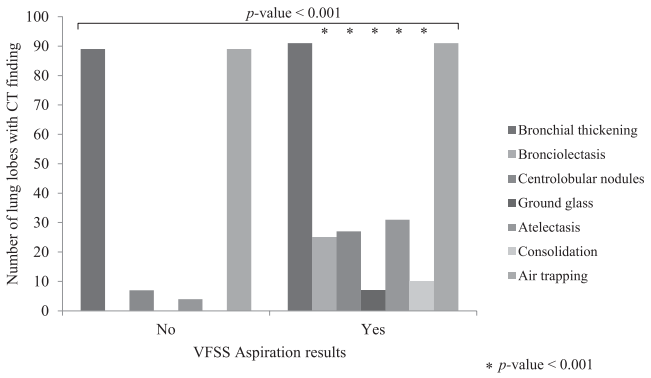


Figure 2. CT findings in patients with pulmonary aspiration detected by videofluoroscopic swallowing study. LLL, left lower lobe; LNG, lingular segment; LUL, left upper lobe; ML, middle lobe; RLL, right lower lobe.

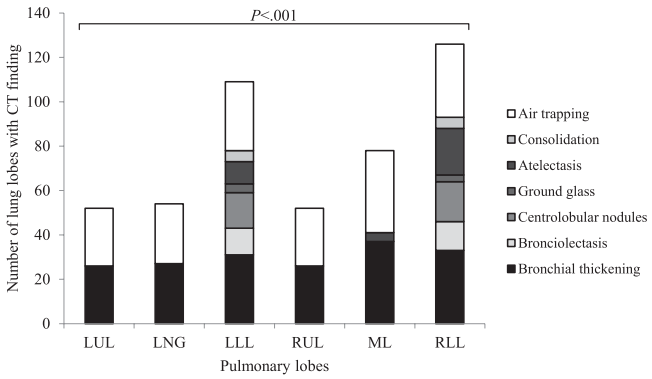
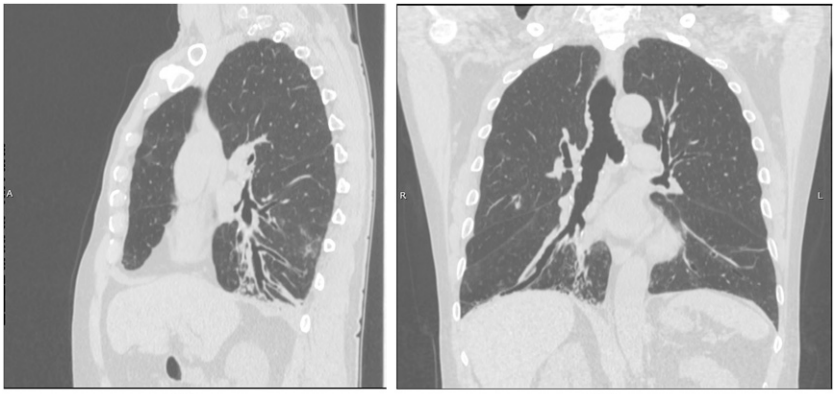


Figure 3. A 59-year-old male diagnosed with melanoma 1 year previously, who presented with chronic cough: (a) sagittal oblique CT has demonstrated bronchiolectasis, atelectasis and areas of ground-glass opacity in the lower lobes. (b) Coronal CT has provided a better visualization of bronchiectasis in the right lower lobe.



(a) (b)

CT findings

The aspiration group comprised 28 participants. The most frequent CT findings were bronchial wall thickening (54%), air trapping (54%), atelectasis (18%), centrilobular nodules (16%) and bronchiolectasis (15%), followed by consolidation (6%) and ground-glass opacities (4%) (Table 1).

The control group (non-aspiration group) comprised 28 patients. The most prevalent abnormalities were bronchial wall thickening (53%) and air trapping (53%), followed by centrilobular nodules (4%) and atelectasis (2%) (Table 1).

Bronchial thickening and air trapping were slightly more prevalent in the aspiration group than in the control group (Figures 1 and 2), but these differences were not significant ($p = 0.208$). In the aspiration group, the main CT findings were observed in the left and right lower lobes ($p < 0.001$) (Figure 3). Bronchiolectasis, centrilobular nodules, ground-glass opacities, atelectasis and consolidation were significantly more common in patients with aspiration than in control subjects (all $p < 0.001$) (Figures 4 and 5). Bronchial wall thickening and air trapping occurred in all lung zones ($p = 0.208$).

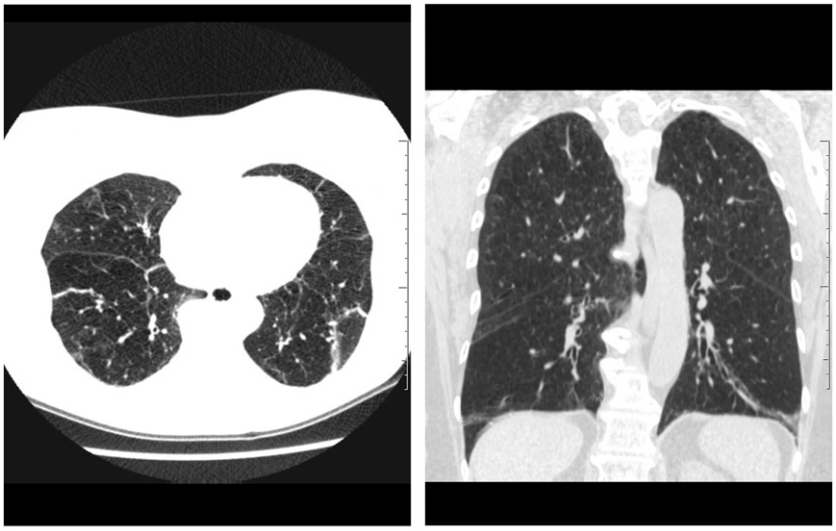
DISCUSSION

Aspiration, defined as the entry of any food into the airway and lung,[14] occurs mainly in patients with dysphagia.[5,15] The imaging findings of aspiration are numerous and often non-specific.[6] In our study, patients with aspiration were more likely than those in the control group to exhibit atelectasis, centrilobular nodules, bronchiolectasis, consolidation and ground-glass opacities, with a significant predilection for the

Figure 4. A 75-year-old female diagnosed with colon cancer 2 years previously, who presented with chronic cough: (a, b) axial expiratory CT has demonstrated areas of ground-glass opacity in the left lower lobe. (c) Axial CT with mediastinal windows has demonstrated a hiatal hernia.

(a) (b) (c)

Figure 5. A 82-year-old female diagnosed with colon cancer 3 years previously, who presented with chronic cough: (a) axial expiratory CT has demonstrated areas of bronchial thickening, atelectasis and areas of ground-glass opacity in the lower lobes. (b) Coronal CT has provided a better visualization of atelectasis and bronchial thickening in the lower lobes.



(a) (b)

lower lobes. Komiya et al[16] described similar findings, demonstrating that ground-glass attenuation, centrilobular nodules, consolidation and atelectasis were more frequent and that lung opacities were seen in lower or diffuse zones. However, patients in that study had acute pulmonary symptoms and no control group was included. In both studies, the distributions were characterized by CT findings of gravitational dependence.

Patients with neurological disorders, dementia and laryngeal and oesophageal dysfunction have been shown to be at increased risk for chronic aspiration, and the efficiency of the swallowing mechanism also decreases with age.[14,15] The authors of a study describing CT findings in healthy older adult aspirators and non-aspirators, as detected by the flexible endoscopic evaluation of swallowing, justified the lack of a significant difference between groups by pointing out pulmonary alterations in non-aspirators, likely owing to the mean age (76 years) of this group.[12] Flexible endoscopic evaluation of swallowing is a safe, portable screening test for aspiration, but it cannot always replace the VFSS for the identification of the presence of aspiration.[17]

The VFSS evaluates oropharyngeal disorders and is the main instrumental method of dysphagia diagnosis. During this examination, participants swallow foods of different consistencies with barium sulfate contrast; manoeuvres and facilitating postures can be tested to contribute to the planning of rehabilitation.[18] Hind et al[19] described the high degree of accuracy of videofluoroscopic images for the identification of aspiration. Because of this accuracy, the VFSS is indicated for the assessment of the function and morphology of the pharynx and cervical oesophagus, specifically with regard to aspiration.[20]

The results of some small studies have been used to recommend the diagnosis of pulmonary microaspiration based on clinical symptoms and risk factors, which consist basically of oesophageal disorders (*e.g.* gastro-oesophageal reflux).[11] The findings reported in these studies were centrilobular nodules and ground-glass opacities, with a random distribution in the lungs. In addition, patients demonstrating aspiration in the VFSS have been found to be approximately 10 times more likely to develop pneumonia than those with a normal swallowing function.[21] Otherwise, CT findings could help in the detection of asymptomatic aspiration in patients undergoing CT for other indications. In this setting, establishment of the pulmonary CT pattern of chronic aspiration is important for the rapid diagnosis of this life-threatening disease.[22]

Some limitations of our work should be addressed. The present study was not prospective or randomized, and many patients were excluded owing to previous pulmonary changes. In addition, CT records were not available for several patients with aspiration. For these reasons, we could not include a larger number of patients.

In summary, we observed significantly different radiological patterns on chest CT between patients with aspiration and a control group. Atelectasis, centrilobular nodules, bronchiolectasis, consolidation and ground-glass opacities occurred more frequently in patients with aspiration, with a pronounced tendency to occur in the lower lobes.

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