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FULL PAPER

The usefulness of low-dose CT scan in elderly patients with suspected acute lower respiratory infection in the emergency room

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Objective: To evaluate the usefulness of low-dose CT (LDCT) for the diagnosis of acute lower respiratory infection (ALRI) in elderly patients in the emergency room (ER).

Methods: A total of 160 consecutive patients (mean age: 75.9 ± 9.2 years; range: 60–97 years), who were diagnosed to have ALRI by LDCT in the ER, were enrolled in this study. Initial chest radiograph (CR) and CT patterns of ALRI were analysed, and clinical courses of patients were assessed.

Results: 49 patients showed negative CR, in whom the main CT patterns were diffuse bronchial wall thickening ($n = 23$), ground-glass opacity ($n = 6$), mixed centrilobular nodules and ground-glass opacity ($n = 3$), small consolidation ($n = 8$) or consolidation in the dependent lung ($n = 9$), while the other 111 patients with the main CT pattern of consolidation demonstrated pulmonary

abnormality on CR. Pulmonary oedema (12.5%) and pleural effusion (23.1%) were associated. The rate of hospitalization, care in the intensive care unit, mortality and comorbidity were significantly higher in the CR(+)LDCT(+) group (88.3%, 36.1%, 18.2% and 59.5%) than in the CR(–)LDCT(+) group (55.1%, 8.2%, 2.0% and 38.8%; $p \leq 0.05$).

Conclusion: LDCT was useful for the early diagnosis of ALRI in elderly patients who showed negative initial CR. The patients with negative initial CR had main CT patterns of diffuse bronchial wall thickening, ground-glass opacity, centrilobular nodules, small consolidation or consolidation in the dependent lung on LDCT.

Advances in knowledge: The use of LDCT may be considered for the early diagnosis of ALRI in elderly patients who have high comorbidity.

INTRODUCTION

With increasing global life expectancy and the number of persons aged 65 years and older in the general population, the population of the elderly suffering from acute lower respiratory infection (ALRI) is increasing. Elderly people are more susceptible to pulmonary infection, owing to their decreased immunity and chronic comorbid illness. Complications, including septic shock or acute respiratory distress syndrome, can be life threatening. However, the diagnosis of ALRI in the elderly is often difficult owing to its non-specific manifestations,¹ because the symptoms and signs in elderly patients can differ from the general population and are sometimes not specific.

A chest radiograph (CR) is required during routine evaluations to establish the diagnosis of pneumonia and to aid in differentiating pneumonia from other common causes of cough and fever, such as acute bronchitis. However, it has limited sensitivity and specificity, and interpreting CRs is often complicated by pre-existing cardiopulmonary

diseases in elderly patients. Low-dose CT (LDCT) is sometimes performed in patients with suspected ALRI, since LDCT is superior to CRs in the detection of pneumonia.^{1–4}

The Infectious Diseases Society of America/American Thoracic Society (IDSA/ATS) consensus on the management of community-acquired pneumonia is that the role of CT scans in the diagnosis of pneumonia is inconclusive. Instead, for patients with a negative CR but toxic appearance suggestive of more than bronchitis, the IDSA/ATS recommends repeating the CR.⁵ However, for elderly patients, who commonly experience low immunity and chronic comorbidity, as well as non-specific clinical symptoms, the benefit of LDCT diagnosis for the proper management of these patients may overcome the radiation hazard and high cost of CT scans.

The purpose of the present study was to assess the usefulness of LDCT in elderly patients with suspected ALRI in

an emergency room (ER) setting. We analysed the CT patterns of ALRI and associated pulmonary lesions and also assessed the clinical courses of patients, with comparison between patients with negative CR and positive CR.

METHODS AND MATERIALS

Study population

This retrospective study was conducted in a single tertiary reference hospital (Ehwa Womans University, Mokdong Hospital) and approved by our institutional review board. A total of 205 consecutive elderly patients underwent LDCT under clinical impression of ALRI in our ER between January 2012 and May 2012. The time interval between initial CR and LDCT was within 12 hours. The indication of CT scan included acute fever or dyspnoea with no definite abnormalities indicated on the CR, underlying pulmonary diseases complicating CR interpretation or low-confidence CR diagnosis by the clinicians.

Among them, 160 patients (103 males and 102 females; mean age: 75.9 ± 9.2 years; range: 60–97 years) who were diagnosed to have ALRI by LDCT and clinical information were enrolled in this study. 45 patients with negative LDCT findings for ALRI were excluded and 5 of them had pulmonary diseases other than ALRI, including congestive heart failure with pulmonary oedema ($n = 2$), active pulmonary tuberculosis ($n = 2$), pulmonary embolism ($n = 1$) and lung cancer ($n = 1$).

ALRI was defined as a condition showing clinical symptoms and signs of acute pulmonary infection and pulmonary or bronchial abnormality consistent with acute infection on CR or LDCT. In this study, ALRI was divided into two categories including pneumonia and bronchitis. Pneumonia was defined as an acute pulmonary infection showing pulmonary infiltration of consolidation, ground-glass opacity or centrilobular nodules on CR or LDCT regardless of combined bronchial abnormality, and bronchitis was defined as ALRI in which LDCT showed only diffuse bronchial wall thickening, without pulmonary parenchymal lesions. All medical charts were reviewed by an internist (JHL), blinded to the patients' imaging findings, for past medical histories, laboratory findings and hospital course including treatment for ALRI.

Chest radiograph and low-dose CT examinations

Chest radiographic examinations were conducted using a caesium iodide–amorphous silicon flat-panel detector digital radiography system (DigitalDiagnost; Philips Medical Systems, Best, Netherlands). Standard anteroposterior CRs (tube voltage: 125 kVp; tube current: automatic exposure control; sensitivity: 250; and pixel size: $143 \times 143 \mu\text{m}$) were performed in an erect position; however, for patients who were unable to stand unassisted during the examination, a supine anteroposterior radiograph was obtained instead.

LDCT was performed with a 16-channel multidetector CT scanner (SOMATOM[®] Sensation 16; Siemens Medical Solutions, Forchheim, Germany) or a 64-channel multidetector CT scanner (SOMATOM Sensation 64; Siemens). The LDCT parameters were as follows: tube voltage: 100 kVp; tube current: 30 mA (effective); collimation: $1 \times 16 \times 1.5 \text{ mm}$ (16 channel) or

$1 \times 64 \times 1.2 \text{ mm}$ (64 channel); pitch: 1.0 (16 channel) or 1.4 (64 channel); and gantry rotation time: 0.5 s. All CT scans were obtained without intravenous contrast enhancement from the thoracic inlet to the upper abdomen, including both adrenal glands.

Image analysis

The initial CR and LDCT scans were reviewed by two radiologists (YK and SSS, with 17 and 12 years' experience in CR and CT, respectively) by consensus on a workstation. The readers had no knowledge of clinical or laboratory data, other than the age and sex of the patient.

In the CR analysis, the radiologists were instructed to record the presence or absence of pulmonary opacity, which is suggestive of ALRI. An equivocal CR was interpreted as negative for ALRI.

After a 2-week interval, the same radiologists interpreted the LDCT findings, blinded to the CR results. In LDCT analysis, they recorded the presence of findings of ALRI including consolidation, ground-glass opacity, centrilobular nodules or diffuse bronchial wall thickening, as well as other combined pulmonary or pleural findings.

In each patient, the main pattern of ALRI was also recorded according to the following classifications: (1) consolidation pattern, when consolidation was observed in the lung, regardless of the presence of other findings of ALRI, such as ground-glass opacity, centrilobular nodules or bronchial wall thickening; (2) ground-glass opacity pattern, when only ground-glass opacity was observed; (3) centrilobular nodule pattern, when only centrilobular nodules were observed; (4) diffuse bronchial wall thickening pattern, when only diffuse bronchial wall thickening was observed; and (5) mixed pattern, when more than two distinct classifications (*i.e.* ground-glass opacity, centrilobular nodules or diffuse bronchial wall thickening) were observed.

On the CT scans, patterns of consolidation, ground-glass opacity, centrilobular nodules or mixed pattern were diagnosed as pneumonia, while patterns of diffuse bronchial thickenings were diagnosed as bronchitis.

Statistical analysis

Continuous variables are reported as means $\pm$ standard deviation and categorical variables as frequencies or percentages. The two groups of patients were compared with respect to their clinical and imaging characteristics: the positive CR/positive LDCT [CR(+)LDCT(+)] group and the negative CR/positive LDCT [CR(–)LDCT(+)] group. The Mann–Whitney *U* test was used for continuous variables and the χ^2 test for categorical variables. All statistical analyses were performed using the SPSS[®] software (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL). *p*-values of less than 0.05 were considered to indicate statistical significance.

RESULTS

In a total of 160 patients, 111 patients showed positive findings on both CR and LDCT scans [these patients were classified as

Figure 1. Inclusion and exclusion criteria: patients with positive chest radiograph (CR) and positive low-dose CT (LDCT) of the chest for acute pulmonary infection, CR(+)LDCT(+), and patients with negative or equivocal CR but positive low-dose CT, CR(-)LDCT(+).

CR(+)LDCT(+)], resulting from pneumonia. The other 49 patients demonstrated positive findings only on LDCT scans, with normal or equivocal CR results (*i.e.* CR(-)LDCT(+) group), resulting from pneumonia ($n = 26$) and bronchitis ($n = 23$) (Figure 1).

Bacteriological confirmation was obtained in only 58 of the 160 patients, of which most patients underwent culture studies or urine antigen tests. The isolated microorganisms included staphylococcal species, such as *Staphylococcus aureus* ($n = 15$), *Staphylococcus pneumoniae* ($n = 9$), klebsiella ($n = 8$), yeast ($n = 7$), *Pseudomonas aeruginosa* ($n = 5$), Gram-negative bacilli ($n = 4$), influenza ($n = 3$) and *E. coli* ($n = 4$); multiple microorganisms were isolated in three patients (*S pneumoniae*, influenza; *S pneumoniae*, acinetobacter; and klebsiella, candida). Mycobacterium species, which were not considered to be the causative pathogen of ALRI, were isolated in seven patients ($n = 7$).

In LDCT analysis, the main CT patterns were consolidation ($n = 128$ patients), diffuse bronchial wall thickening ($n = 23$), ground-glass opacity ($n = 6$), mixed centrilobular nodules and ground-glass opacity ($n = 3$). CRs were interpreted as negative in all patients with CT patterns of diffuse bronchial wall thickening, ground-glass opacity and mixed centrilobular nodules and ground-glass opacity and 17 patients with consolidation in whom consolidation was small ($n = 8$) or located in dependent areas of the lung ($n = 9$) (Table 1). CRs were positive in 111 patients who demonstrated consolidation on LDCT.

The demographics, clinical course and outcome of the study population are summarized in Table 1. The CR(-)LDCT(+) group showed a significantly higher number of female patients ($p = 0.001$) and lower rate of comorbidity ($p = 0.048$) than the CR(+)LDCT(+) group. In the hospital courses, the CR(-)LDCT(+) group also showed significantly lower rates of hospitalization and antibiotic therapy than the CR(+)LDCT(+) group.

Table 1. Comparison of the clinical diagnosis and CT pattern of acute lower respiratory infection between the positive chest radiograph and low-dose CT group [CR(+)LDCT(+)] and negative radiograph and positive CT group [CR(-)LDCT(+)]

Patients	Main CT pattern	Number of patients ($n = 160$)
CR(-)LDCT(+) ($n = 49$)	Diffuse bronchial wall thickening	23
	Ground-glass opacity	6
	Mixed centrilobular nodules and ground-glass opacity	3
	Small consolidation	8
	Consolidation in the dependent lung ($n = 9$)	9
CR(+)LDCT(+) ($n = 111$)	Consolidation	111

Table 2. Comparison of demographics and clinical course between the CXR(–)LDCT(+) and CXR(+)LDCT(+) groups

Variables	CXR(–)LDCT(+) (<i>n</i> = 49)	CXR(+)LDCT(+) (<i>n</i> = 111)	<i>p</i> -value
Age (years)	77.0 ± 9.4	75.1 ± 9.5	0.044
Sex (M:F)	17:32	69:42	0.001
Comorbidity	19/49 (38.8%)	66/111 (59.5%)	0.048
1 ^a	15 (30.6%)	39 (35.1%)	
2 ^a	4 (4.1%)	22 (19.8%)	
3 ^a	0	5 (4.5%)	
Hospitalization	27/49 (55.1%)	83/94 ^b (88.3%)	0.000
Non-ICU	23/49 (46.9%)	49/94 (52.1%)	
ICU	4/49 (8.2%)	34/94 (36.1%)	
Antibiotic therapy	32/49 (65.3%)	104/105 ^c (99.0%)	0.000
Per oral	5/49 (10.2%)	8/105 (7.6%)	
Intravenous	27/49 (55.1%)	96/105 (91.4%)	
Mortality	1/49 (2.0%)	16/88 ^d (18.2%)	0.001

CXR(–)LDCT(+), normal or equivocal findings on CXR but positive on LDCT; CXR(+)LDCT(+), positive findings on both CXR and LDCT; F, female; ICU, intensive care unit; M, male.

^aNumber of comorbid illnesses.

^bSelf-discharge or transfer: 17 of the total 111 patients undergoing CXR(–)LDCT(+).

^cSelf-discharge or transfer without medication: 6 of the total 111 patients.

^dUnavailable to assess mortality due to self-discharge or transfer: 23 of the total 111 patients.

group ($p = 0.000$), but about half of these patients (55.1%) needed hospitalization with intravenous antibiotic therapy, of whom four patients (8.2%) needed care in the intensive care unit (ICU); one of the patients (2.0%) died of combined heart failure. In the CXR(+)LDCT(+) group, 83 (88.3%) patients were hospitalized with 34 patients in the ICU; 16 (18.2%) of these patients died during hospitalization (Table 2).

As combined pleuropulmonary abnormalities, which occurred in conjunction with ALRI, pulmonary oedema and pleural effusion were found in 20 (12.5%) and 37 (23.1%) patients, respectively. A total of 69 cases of pre-existing pulmonary diseases were found, including pulmonary emphysema ($n = 27$), bronchiectasis ($n = 16$) and fibrosis, owing to previous tuberculous infection or other causes ($n = 26$). Incidental findings include lung cancer ($n = 1$), active pulmonary tuberculosis ($n = 1$) and asbestosis ($n = 1$) (Table 3).

DISCUSSION

Although CRs are used for the routine evaluation of patients with suspected pneumonia in the ER, low sensitivity and specificity are major limitations of CR, compared with those of CT.^{1–4,6–9} CT, proven to be especially helpful when the CR diagnosis is unclear, has been mostly used as a supplement examination for pneumonia, as recommended by the 2007 IDSA/ATS consensus guidelines for community-acquired pneumonia.⁵ In addition, outcome-based literature on the value of chest CT in adults with pneumonia who are immune competent is to date limited.

In the present study, patients who showed diffuse bronchial wall thickening, ground-glass opacity, centrilobular nodules or small

consolidation on CT scan demonstrated equivocal or negative findings on radiographs, implying that patients could have been missed when they were examined only with radiographs. A demonstrative case is shown in Figure 2. The use of LDCT may facilitate the timely use of antibiotics in those patients, considering that antibiotic therapy is recommended for the management of acute bronchitis as well as pneumonia in the elderly with comorbidities.¹⁰ Our study also showed the diagnostic value of CT in aspiration pneumonia. The dome of the diaphragm may project over a significant portion of the anterior

Table 3. Combined pleuropulmonary abnormalities in 160 patients with acute pulmonary infection (ALRI)

Pleuropulmonary abnormalities	Number of patients
ALRI-related lesions	
Pulmonary oedema	20 (12.5%)
Pleural effusion	37 (23.1%)
Pre-existing pulmonary diseases	
Emphysema	27 (16.9%)
Bronchiectasis	16 (10.0%)
Fibrosis due to previous infection	26 (16.3%)
Incidental findings	
Lung cancer	2 (1.3%)
Active pulmonary tuberculosis	1 (0.6%)
Asbestosis	1 (0.6%)

Figure 2. A 72-year-old male presented to the emergency department with fever and cough. (a) The anteroposterior chest radiograph obtained in the supine position was interpreted as equivocal for pneumonia. (b) Low-dose chest CT scan revealing consolidation and ground-glass opacity in the dependent areas of both lower lobes, which are suggestive of aspiration pneumonia. The patient was admitted to the hospital and treated with intravenous antibiotic therapy.

and basilar lung fields, obscuring findings and making the interpretation of CRs difficult.³ Considering the high rate of comorbidity in patients with aspiration pneumonia, LDCT of the chest may change the management and decrease mortality rates in these patients. A demonstrative case is shown in Figure 3.

The results of this study demonstrate that the negative CR and positive CT population had a better clinical course than the positive CR population; they were treated more often with ambulatory care and oral antibiotics, required ICU care less frequently and rarely died from pneumonia. The better outcome of these patients presumably simply relates to having less extensive disease. Still, 55% and 8% of the CR negative group needed admission and ICU care, respectively. Several studies showed that delayed transfer to the ICU was associated with higher rates of adverse outcomes.^{11–13} Although the ICU admission decision is often restricted by clinical manifestations,^{5,13} identification of pneumonia with chest CT when patients show equivocal CR may help in making prompt decisions to admit patients from the ER (Figure 4).

The effective radiation dose of LDCT (range: 1.0–1.5 mSv) is lower than that used for a contrast-enhanced standard CT

examination (3–8 mSv). Also, LDCT does not require iodine contrast use, which may decrease renal function in elderly patients. There has been growing recognition of the benefit of improved diagnostic accuracy of chest CT over its radiation risk,^{4,14,15} particularly in the high-risk group, such as patients who are immune compromised.^{8,16,17} Low-dose chest CT seems to have a favourable risk-to-benefit ratio for elderly patients. They have a shorter expected life span, with a relatively lower cumulative radiation risk, than the younger population. In addition, the elderly have decreased immunity, which leads to the high mortality rates from pneumonia.

This study had several limitations. First, there can be a potential heavy selection bias in the patient population in terms of retrospective nature and including only the patients who visited ER with acute respiratory symptoms. Also, as this study did not include a control group of patients who had only CR examinations, the assessment of clinical course and outcome by adding LDCT was limited in the current study. Further prospective randomized controlled design would address the issue of clinical outcome by adding LDCT in elderly patients. Second, CT scan might be obtained in patients with more comorbidities or serious clinical conditions and that might

Figure 3. A 74-year-old male presented to the emergency department with cough. (a) The posteroanterior chest radiograph was considered as equivocal. (b) Low-dose chest CT scan demonstrating diffuse bronchial wall thickening in both lower lungs, consistent with bronchitis. The patient was treated with oral antibiotics at an outpatient clinic.

Figure 4. A 72-year-old male presented to the emergency department with mild fever and dyspnoea. (a) The anteroposterior supine chest radiograph showing suspicious opacity in the right lower lung zone. (b) Low-dose chest CT scan revealing focal consolidation in the right middle lobe. The patient was admitted to the hospital and treated with intravenous antibiotic therapy.

result in a high rate of hospitalization and a case of mortality in patients with negative CR. Third, the CR was obtained in the supine position in most patients who presented with toxic appearance at the ER; this may have decreased the rate of positive CR particularly in patients with aspiration pneumonia. Finally, the findings of diffuse peribronchial thickenings only on LDCT could be the result of a chronic condition such as chronic bronchitis rather than ALRI. However, we tried to minimize false positives by diagnosing ALRI according to the clinical symptoms and signs by the clinician as well as imaging findings.

In conclusion, LDCT was useful for the early diagnosis of ALRI in elderly patients with negative initial CR. The patients with negative initial CR had main CT patterns of diffuse bronchial wall thickening, ground-glass opacity, centrilobular nodules, small consolidation or consolidation in the dependent lung on LDCT. Therefore, in the clinical setting of elderly patients with severe or progressive symptoms, comorbidities or a risk of aspiration pneumonia, LDCT may be recommended for the early diagnosis and management of ALRI and decreasing mortality when patients show negative initial CR.

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