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Acute Respiratory Distress Syndrome (ARDS) : HRCT Findings in Survivors[1]

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The purpose of this report is to describe the high-resolution computed tomography (HRCT) findings of the lung in survivors of acute respiratory distress syndrome (ARDS). Among eleven patients who survived ARDS for one year, chest radiography and HRCT revealed pulmonary fibrosis in four. Causes of ARDS included pneumonia during pregnancy, near drowning, pneumonia during liver cirrhosis, and postoperative sepsis. Thoracoscopic biopsy and histopathologic correlation were available in one patient.

HRCT showed diffuse interlobular septal thickening, ground glass opacity, parenchymal distortion, and traction bronchiectasis. Fuzzy centrilobular nodules were seen in two patients and one patient had multiple, large bullae in the left hemithorax. In all patients, lesions affected the upper and anterior zones of the lung more prominently. The distribution of pulmonary fibrosis was characteristic and reflected the pathogenesis of lung injury; fibrosis was largely due to hyperoxia caused by ventilator care. In one patient, histopathologic correlation showed that imaging findings were accounted for by thickening of the alveolar septum along with infiltration of chronic inflammatory cells and fibrosis. Fuzzy centrilobular nodules corresponded with bronchiolitis.

Index words : Lung, CT
Lung, fibrosis
Computed tomography (CT), high-resolution

Acute lung injury, the most severe form of which is ARDS is defined as rapid alteration of the alveoli that results in impairment of gas exchange. Despite improvement in supportive care for patients with acute lung injury, the mortality rate for ARDS has hovered around the 50 % for the past decade (1). Recent studies have suggested that once a patient has survived initial injury, subsequent gas exchange problems may arise in part from an inadequately regulated healing response (2).

Although the plain radiographic and CT findings of ARDS are well known, HRCT findings in survivors of ARDS have not been fully evaluated. We recently encountered four patients who survived from ARDS who were diagnosed according to the definition of Murray et al. (3). We describe the chest radiographic and HRCT findings in these cases, and believe they may explain the pathogenesis of fibrotic lung.

Case 1

A 30-year-old pregnant woman at gestational week 35

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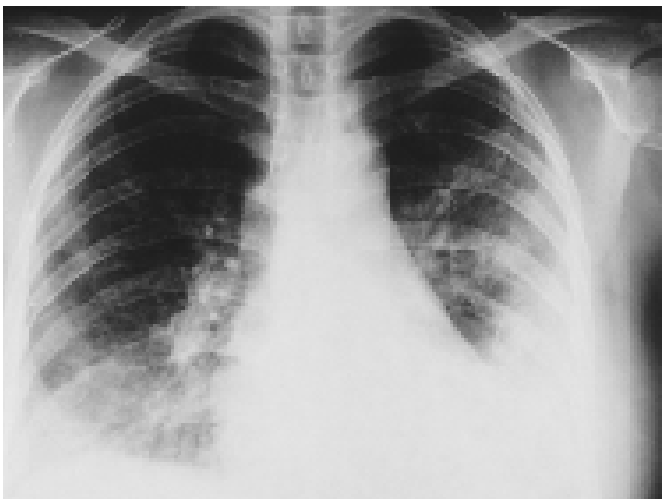
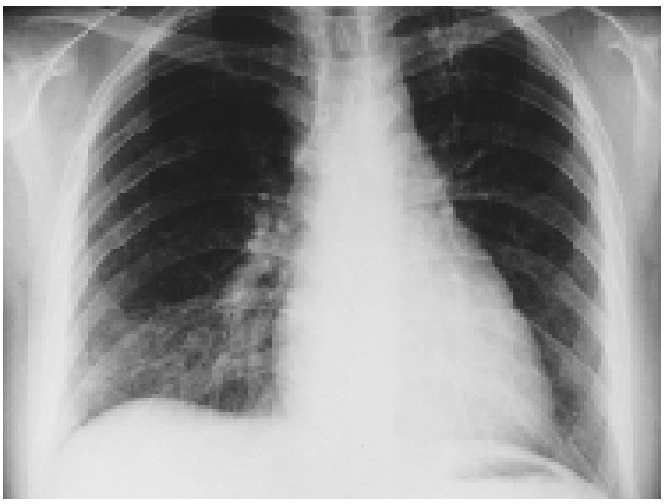
was admitted with complaints of chronic cough and dyspnea. Arterial blood gas analysis showed pH 7.402, PCO_2 25.3 mmHg, and PO_2 55.2 mmHg. Body temperature was 39.2 ℃. A chest radiograph revealed ill defined patchy opacity in both lungs and consolidation in the left lower lung (Fig. 1A). Two days later, radiography showed diffuse haziness and consolidation in both lungs. The baby was delivered normally and a ventilator was applied. Follow-up chest radiographs revealed gradual resolution of the haziness in both lungs. *Chryseobacterium meningoseptum and Buckhholderia pickketti* were cultured in the sputum. About a month later, persistent ground glass opacity and coarse reticular density were seen on chest radiographs in the left upper, and right middle and lower lobes (Fig. 1B). A pulmonary function test performed two and a half months later revealed a severely restrictive pattern and diffusion defect. HRCT performed on the 98th hospital day showed diffuse ground glass opacity with interlobular septal thickening in both the upper and mid-lung zones. Diffuse bronchial dilatation and mild architectural distortion were also noted. Involvement of the anterior aspect of the lung predominated (Fig. 1C). Follow-up chest radiography indicated that pulmonary fibrosis remained unchanged. A summary of this case can be found in Table 1.

Case 2

A 43-year-old woman came close to drowning and received cardio-pulmonary resuscitation. A chest radiograph obtained at that time showed diffuse ground glass opacity and patchy consolidation in both lungs. Six days later, she was severely dyspneic and arterial blood gas analysis showed pH 7.47, PaO_2 50.1 mmHg, PCO_2 44.7 mmHg, and SaO_2 87.1 %. Ventilation was started. Chest radiography again revealed persistent ground glass opacity and consolidation in both lungs though, a follow-up chest radiograph obtained three weeks later



A



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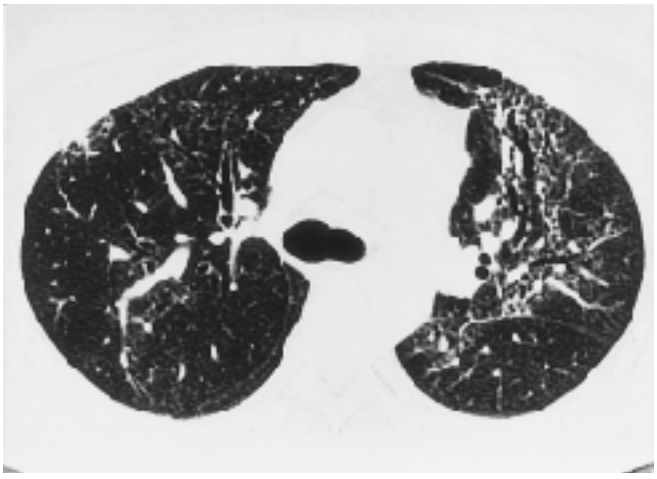


C

Fig. 1. A. Chest radiograph showed ill defined patchy opacity in the both lungs and consolidation in the left lower lung.
B. Follow up chest radiograph (85 days after the onset of ARDS) shows coarse reticular densities and ground glass opacities in the left upper, and right middle and lower lobes.
C. HRCT (97 days after the onset of ARDS) at the level of aortic arch shows interlobular septal thickening with bronchial dilatation and mild architectural distortion in the left upper lobe. Fibrotic change is also seen in the subpleural portion of the right upper lobe. Anterior aspects are predominantly involved.

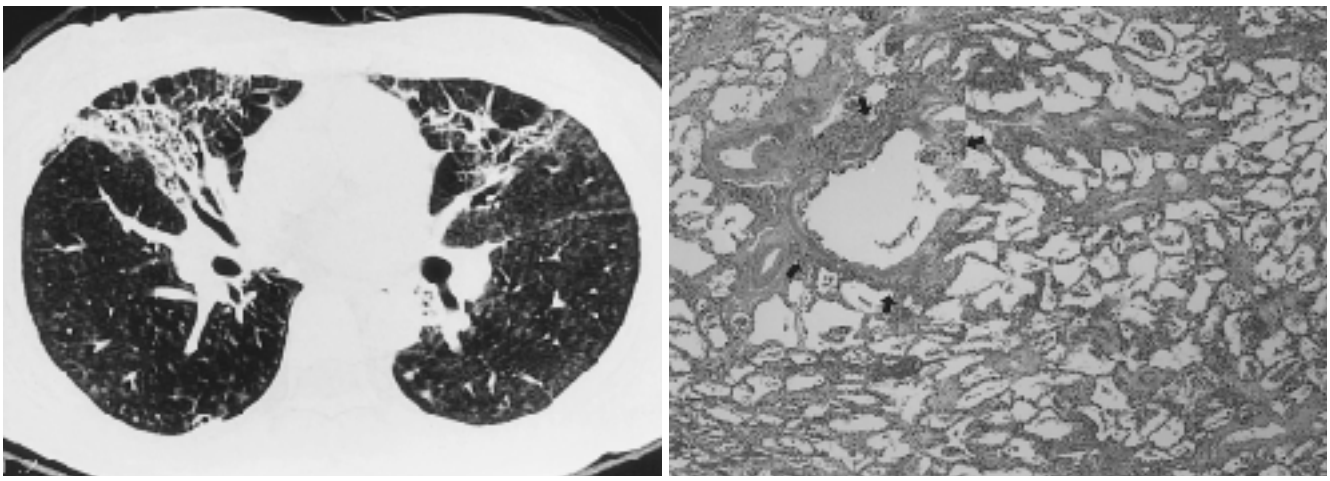
showed resolution of the consolidation. Coarse reticular density and patchy ground glass opacity were noted in both lungs. HRCT performed on the 37th hospital day showed diffuse interlobular septal thickening and ground glass opacity in both lungs, these features were more prominent in the upper and anterior lung zones than in the posterior and lower zones. Fuzzy centrilobular nodules were also noted throughout the entire lungs, without zonal predominance (Fig. 2A) (Table1). In order to determine disease activity, thoracoscopic biopsy of the right middle lobe was performed on the 46th admission day. Photomicroscopy showed thickening of the alveolar septum together with infiltration of chronic inflammatory cells and mild fibrosis. Foci of atelectasis with alveolar macrophage accumulation and hemorrhage in alveolar spaces and proliferation of type II pneumocytes were also seen, and associated dilated bronchioles and bronchiolitis were noted (Fig. 2B). A pulmonary function test showed moderate restrictive airway disease and diffusion defect. Because of inflammation and fibrosis, the patient was placed on high dose steroid therapy. Follow-up chest radiography revealed resolution of ground glass opacity and reticular density.

Case 3

A 68-year-old woman was admitted because of Parkinsonism and hepatic encephalopathy and three weeks later, began to complain of dyspnea. A chest radiograph showed total haziness of the left lung and arterial blood gas analysis showed pH 7.387, PaO_2 54.7 mmHg, PCO_2 45.7 mmHg, and SaO_2 84.2 %. Hypoxia improved after ventilation, and Klebsiella pneumoniae was identified in blood culture. After treatment with antibiotics, consolidation was completely resolved, but because of weaning failure, ventilation was continued. On the 46th admission day, the patient lapsed into a coma with a high temperature. A chest radiograph revealed total haziness, with air-bronchograms in the right lung and ill defined haziness in the left (Fig. 3A). Haziness and consolidation were extended to both lungs, but eight days

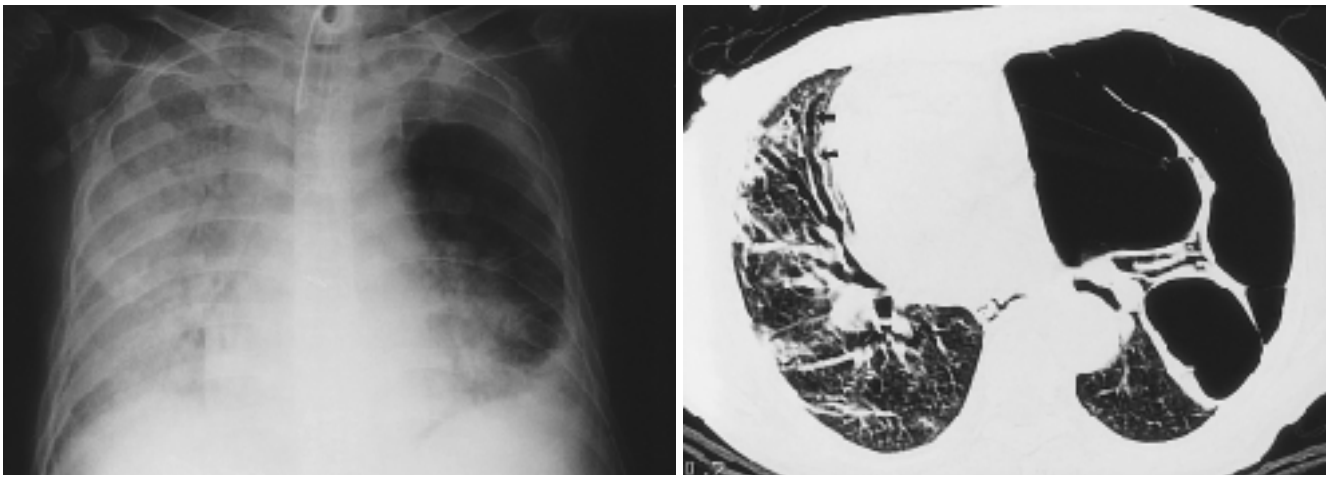
Table 1. Summary of Patients Characteristics

	Sex	Age	Smoking History	Causes of ARDS	Total duration of ventilatory assistance (days)	Duration of $FiO_2 > 0.6$(days)	HRCT (days after the ARDS)
Case 1	F	30	-	Pneumonia during pregnancy	23	4	97
Case 2	F	43	-	Near drowning	18	2	31
Case 3	F	68	-	Pneumonia in liver cirrhosis	180	4	100
Case 4	M	58	+	Postoperative sepsis	13	2	30



A B

Fig. 2. A. HRCT (31 days after the onset of ARDS) shows fibrosis in both lungs. Involvement is more prominent in the upper and anterior lung zones than in the lower and posterior zones. Fuzzy centrilobular nodules are also seen throughout the entire lung fields, suggesting bronchiolitis.
B. Photomicroscopic examination (H-E stain, ×40) reveals thickening of alveolar septum with infiltration of chronic inflammatory cells and mild fibrosis. Bronchioles are dilated and bronchiolitis is associated (arrows).



A B

Fig. 3. A. Chest radiograph (onset of ARDS) shows total haziness with air-bronchograms in the right lung and ill - defined haziness in the left lung.
B. HRCT (100 days after the onset of ARDS) shows interlobular septal thickening with ground glass opacity in the right lung. Subpleural lines are also seen. Bronchi are diffusely dilated (arrows). The left lung is replaced by large bullae.

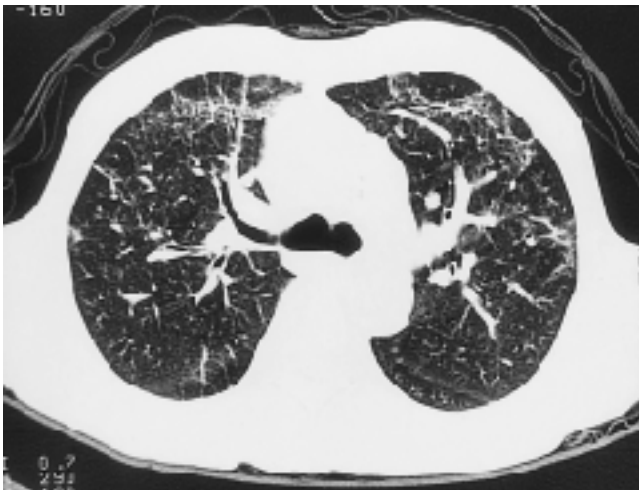


Fig. 4. HRCT (30 days after the onset of ARDS) shows interlobular septal thickening with ground glass opacity in the anterior aspects of both upper lung zones.

later, improved markedly. Newly developed diffuse reticular density and ground glass opacity were seen in the right lung, however, and the left lung showed multiple radiolucent bullae at its periphery. Follow - up showed that bullae in the left lung had become larger and the mediastinum had shifted to the right side. Reticular density with ground glass opacity of the right lung was persistent. HRCT obtained on the 146th admission day demonstrated interlobular septal thickening with ground glass opacity in the right lung, as well as subpleural lines and dilated bronchi. The left lung contained bullae of various sizes (Fig. 3B) (Table 1).

Case 4

A 58-year old man was transferred because of spleen laceration suffered in a traffic accident. It was found incidentally that GB polyp was present, and splenectomy and cholecystectomy were performed. Three days after surgery the patient complained of dyspnea and on the 4th postoperative day, chest radiography revealed ill - defined patchy opacity in both lungs. Arterial blood gas analysis showed pH 7.39, PaO_2 45 mmHg, PCO_2 40 mmHg, and SaO_2 84 % while chest radiography showed ill-defined consolidation in both lung fields. Extensive consolidation in both lungs persisted despite improved arterial blood gas, but consolidation later improved gradually. *Staphylococcus aureus* was identified in blood culture. Chest radiography indicated near - complete resolution of consolidation, but reticular density with patchy ground glass opacity remained in both lungs. HRCT performed on the 30th postoperative day showed diffuse interlobular septal thickening and ground glass opacity in both lungs, mild parenchymal distortion, bronchiectasis, bronchioloectasis, and fuzzy centrilobular nodules. The anterior and upper lung zones were more prominently affected than the posterior and lower lung zones (Fig. 4). On the 32nd postoperative day a pulmonary function test revealed reduced diffusion capacity, indicating loss of functional alveolar capillary surface (Table 1).

Discussion

ARDS is a descriptive term that has been applied to a-

cute and diffuse infiltrative lung lesions of diverse etiology accompanied by severe arterial hypoxemia.

Roentgenographic manifestations are areas of patchy, ill-defined opacity that initially extended throughout both lungs. Twenty - four hours to four days later, patchy zones of consolidation rapidly coalesce to form massive air-space consolidation in both lungs. Characteristically, all lung zones from the apex to the base and to the extreme periphery of the lung are involved (4, 5).

Plain radiographic findings in survivors of ARDS are variable (6-8). Elliot et al. reported survivors whose chest radiograph obtained at an interval between one and 90 weeks after the onset of respiration distress was normal (6, 7). Lakshminarayan et al. (8) described their findings in ten subjects examined at interval of 16 weeks to 42 months after the onset of distress. Chest radiographs were normal in five cases, showed bilateral basal interstitial infiltrates of varying severity in five others, as in our cases, and features of emphysema in one.

Although plain radiographic findings varied, functional abnormalities in survivors of ARDS were persistent (6-10). Elliot et al. (6) reported persistent abnormalities of DLco as in our cases 1, 2, and 4. They also observed persistent abnormalities of oxygen transfer across the lung during exercise, a condition associated with pulmonary fibrosis. Elliot et al (10) explained that functional impairment and pulmonary fibrosis were largely due to hyperoxia caused by ventilator care. Where there was a high fractional concentration of inspired O_2 ($FiO_2 > 0.6$), severity of fibrosis correlated closely with the duration of ventilator care (10). Desi et al recently reported that in patients with acute respiratory distress syndrome, the duration of associated ventilation -in particular, pressure - controlled inverse ratio ventilation is independently related to the extent of reticular pattern seen during follow up CT (11). The variety of plain radiograph features seen in survivors of ARDS is therefore due to the varying duration of hyperoxia during ARDS.

For diagnosis in patients with chronic diffuse infiltrative lung disorders, HRCT is superior to plain radiography (12), detecting more easily the subtle fibrosis seen in survivors of ARDS. HRCT findings have also been shown to correlate closely with the histologic findings of interstitial fibrosis (13). Ground glass opacity usually suggests active inflammation. Interlobular septal thickening is seen in various stages of fibrosis, the end stage being represented by honeycombs. Open-lung biopsy was performed in one of our patients, revealing pulmonary interstitial inflammation and early fibrosis corresponding to HRCT findings of ground glass opacity and interlobular septal thickening.

In survivor of ARDS the affected lung zones were characteristic ; in all four patients the anterior aspect was more prominently affected than the posterior lung zone. An anterior reticular pattern resulted from alveolar overdistention in" unprotected "nonconsolidated lung. During the acute phase of ARDS, hyperattenuated areas of unaerated or collapsed parenchyma are typically seen in dependent parts of the lung. The distribution of pulmonary fibrosis in survivors of ARDS differs from other types of pulmonary fibrosis such as idiopathic pulmonary fibrosis or interstitial lung disease with collagen vascular disease (14, 15).

In one of our patients showed extensive bullae occupied most of the hemithorax. Interstitial emphysema, bullae, and pneumothorax are frequently found during the ARDS support, possibly due to barotrauma (6).

In summary, HRCT findings of the lung in survivors of ARDS are interlobular septal thickening and ground glass opacity with parenchymal distortion and traction bronchiectasis. Fuzzy centrilobular nodules and bullae may be associated. Lesions are more prominent in the upper and anterior lung zones than in the posterior and lower zones.

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급성 호흡 곤란 증후군 : 생존자의 고해상 전산화 단층촬영 소견[1]

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급성 호흡 곤란 증후군(Acute Respiratory Distress Syndrome)에서 생존한 사람의 고 해상도 전산화 단층촬영(HRCT)소견을 알아보고자 하였다. 1년간 급성 호흡 곤란 증후군에서 생존한 사람 11명중 단순 흉부 촬영에서 폐 섬유화가 발견된 4명을 대상으로 하였다. 급성 호흡곤란 증후군의 원인으로는 임신 중 폐렴, 물에 빠진 경우, 간 경화 와 동반된 폐렴, 그리고 수술 후 패혈증이었다. 이들의 고 해상도 전산화 단층촬영 소견과 병변의 분포를 알아보았다. 흉강경 생검을 시행한 1명에서는 조직학적 소견과 비교하였다.

급성 호흡 곤란 증후군 생존자의 고 해상도 전산화 단층촬영 소견은 엽간의 중격 비후, 간유리 음영, 간질 변형, 그리고 견인성 기관지 확장이었다. 2명에게서 불분명한 중심 소엽성 결절이 보였고, 1명은 여러 개의 큰 기포가 한쪽 흉강을 완전히 채우고 있었다. 병변의 분포는 4명의 환자 모두 에서 주로 상엽 과 앞쪽에 저명하였다. 이러한 분포는 급성 호흡 곤란 증후군의 폐 섬유화가 주로 인공호흡기에 의한 고산소증에 의한 것이기 때문이라고 생각되었다. 1예에서 시행한 조직학적 소견과 연관 시켜보았을 때, 방사선학적 소견은 폐간질의 만성 염증세포의 침착과 비후, 섬유화 때문이었다. 불분명한 중심 소엽성 결절은 세 기관지염에 의한 것이었다.