Radiological Study of Bronchiolitis

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細気管支炎のX線診断学的研究

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X線診断学的立場から，各種の臨床検査を行ない細気管支炎と診断した34例について検討を行ない以下の結果をえた．

（1）胸部単純X線撮影時には，吸気的・呼気時の写真を同時に撮影する必要がある．

（2）吸気時胸部単純X線写真に，異常所見が認められない症例が比較的多くみられる．

（3）胸部X線写真上の異常陰影としては，2mm以下の粒状陰影，網状陰影が比較的本症の特徴を表わしている．

（4）胸部単純写真で，2mm以下の粒状陰影が認められる本症の選択的肺胞気管支造影は狭小，分岐欠如，肺胞像出現不均等が多くみられる．胸部X線写真で異常所見が著明になるにつれ，拡張・閉塞の所見が多くみられるようになる．

（5）本症は，終末細気管支狭小化群（I型）と終末細気管支拡張群（II型）が多くみられる．

In recent years, the etiology, clinical picture and pathology of bronchiolitis have been attracting much attention.

As diagnostic methods for the peripheral airway, respiratory physiological diagnosis[1)~6)], selective alveolobronchography (SAB)[7)~9)], endoscopy[10)] and transbronchial lung biopsy[11)~13)] have been developed, and this disease is now being studied from the respective standpoints. However, there are several different views on important points, such as the concept and diagnostic criteria of this disease, and agreement has not been obtained as yet. We have undertaken various clinical examinations as an approach to establish the diagnostic criteria of bronchiolitis from the standpoint of diagnostic radiology and have studied cases diagnosed as bronchiolitis.

Table 1 Clinical data

1.	Patient	34				
2.	Sex	Male	24	Female	10	
3.	Age (average)		50.2			
4.	Past history	Toxic gas 7		No particular 27		
5.	History of smoking	Smoker 11		No smoker 20		Ex-smoker 3
6.	Sputum	(+)	27			Presenting symtoms
7.	Cough	(+)	29			
8.	Dyspnea	(+)	28			
9.	Polycythemia	(+)	3	(−)	31	
10.	Clubbing	(+)	6	(−)	28	

Subjects and Methods

(1) Subjects

The subjects were 34 patients (24 men and 10 women) who were clinically diagnosed as having bronchiolitis upon observation of clinical symptoms, pulmonary function tests, radiography and transbronchial lung biopsy. The age of the subjects ranged from 27 to 79 years, averaging 50.2. They comprised seven patients with a past history of inhalation of organic gas and 27 without any noteworthy history. They were 11 smokers, 3 ex-smokers and 20 non-smokers.

As clinical pictures, hematocytosis and clubbing were found in three and six cases, respectively. Sputum, coughs and dyspnea were distributed and overlapped evenly in almost all cases.

The subjects underwent plain chest X-ray during inspiration and expiration, magnification radiography, selective alveolobronchography with the use of magnification radiography of three to four times, endoscopy, spirometry, and pulmonary function tests mainly including examination of the alveolar-arterial O_2 tension difference ($AaDo_2$).

(2) Radiographic Procedures

In SAB, a bronchofiberscope (BF-1TR, Olympus) or a bronchial catheter 6 mm in outside diameter and 2.5 mm in inside diameter (FBC-6, Machida) is inserted into the bronchus and wedged in the right B^8 under observation by X-ray TV. A polyethylene tube for lavage (2.2 mm in outside diameter), to the tip of which a metal piece with a rounded edge is attached, is inserted from the channel and prewedged in a region where dense abnormal shadows are found on chest X-ray, i.e., B^8a or B^8b, or the periphery of B^9 according to circumstances. A total of 2 or 3 ml of aqueous dionosil is injected little by little under X-ray TV fluoroscopy by the highest magnification. Then, magnification radiography of three to four times is performed by an X-ray apparatus with three-phase alternating current and the bulb of the X-ray tube with a 0.3 mm focal spot, under the exposure conditions of 20 mA, 120 kv, and 2/100-6/100 seconds.

(3) Findings on SAB and Morphological Classification

SAB findings of the peripheral airway were narrowing, dilatation, obstructive discontinuity, poor branching, tortuosity, alveolar duct ectasis, alveolar abnormal figure, and alveolar uneven filling.

On the basis of the normal range of 0.5—0.6 mm obtained from the Weibel's calculations in current use, narrowing and dilatation in radiograms were determined by actual measurement with a loupe in contrast with a catheter 2.0 mm in outside diameter.

The patients' alveolo-bronchograms were morphologically classified into the following groups according to the representative findings, i.e., the major finding that characterized the whole image:

Type I—a group in which narrowing of the bronchioles from the respiratory to the terminal bronchioles was predominant.

Type II—a group in which severe dilatation from the terminal bronchioles to the alveoli was

predominant (Type IIa) and a group in which slight to moderate dilatation from the terminal bronchioles to the alveoli was predominant (Type IIb).

Type III—a group in which alveolar duct ectasis was predominant.

Type IV—a group with highly abnormal figures of the alveoli (Type IVa) and a group with slightly abnormal figures of the alveoli (Type IVb).

Results

1) Comparison of Findings on Various X-ray Examinations

As abnormal shadows in plain chest X-ray films (Table 2) during inspiration, nodular shadows of less than 2 mm were found in 10 patients, followed by reticular shadows in seven, ring-like shadows of less than 5 mm in five, nodular shadows of 2 mm or more in two, and ring-like shadows of 5 mm or more in one. There were no obviously abnormal shadows in nine patients.

The distribution density of abnormal shadows was mild in nine patients, moderate in ten and severe in six. The extent of the shadows was less than one third of the entire lung field in eleven patients, one to two thirds in eight, and more than two thirds in six.

When plain chest X-ray films during inspiration and expiration were compared in 20 patients, excluding those who showed abnormal shadows on X-ray during, inspiration or in whom X-ray during expiration was not undertaken, seven showed increased abnormal shadows during expiration as compared with inspiration, but the others showed no change. Of six patients without any abnormal shadows during inspiration, five showed nodular shadows during expiration.

When plain chest X-ray films during inspiration and plain magnification radiograms were compared in 16 patients, no change, a decrease or disappearance according to the exposure conditions, and an increase were noted regarding abnormal shadows in magnification radiograms in nine, nine and four, respectively. Magnification radiography revealed abnormal shadows in two of four patients who exhibited no abnormal shadows on plain chest X-ray during inspiration.

Morphological classification by SAB (Table 3) was: 18 cases in the group with narrowing of the terminal bronchioles (Type I) (Fig. 1); three in the group with dilatation of the terminal bronchioles (Type IIa); eight in the group with dilatation of the terminal bronchioles (Type IIb) (Fig. 2); three in the group with alveolar duct ectasis (Type III); one in the group with alveolar abnormal figures (Type IVb); and one normal case.

When findings on plain chest X-ray and SAB (Table 4) were compared, patients with nodular shadows of

Table 2 Chest X-ray findings

Findings	Cases
Normal	9
Nodular shadows 2 mm or less in diameter	10
Nodular shadows 2 mm or more in diameter	2
Reticular shadows	7
Ring-like shadows 5 mm or less in diameter	5
Ring-like shadows 5 mm or more in diameter	1

Table 3 Classification of SAB findings

I	II		III	IV		Normal	N
	a	b		a	b		
18	3	8	3	0	1	1	34

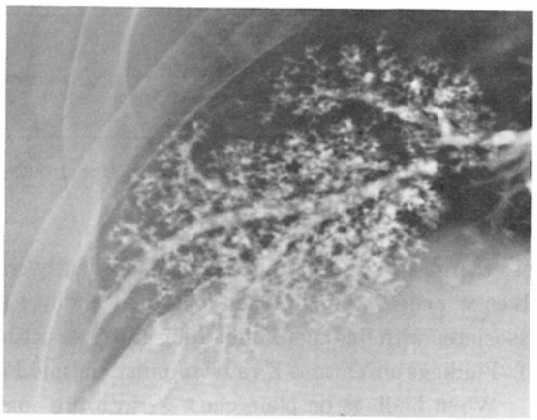

Fig. 1 SAB showed narrowing in the bronchioli and insufficient expansion of the alveoli.

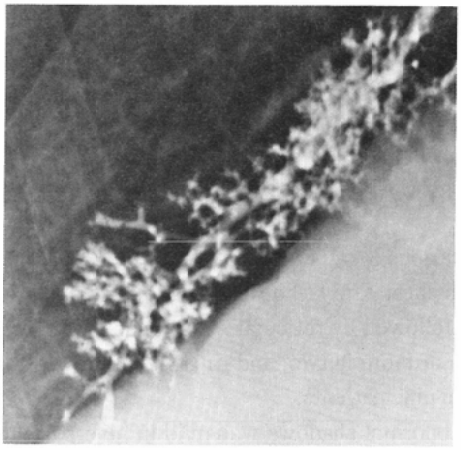

Fig. 2 SAB showed lack of branching and mild dilatation in bronchioli. There was an unbalanced appearance in part of the alveoli.

Table 4 Chest roentgenogram and SAB findings

N=25

SAB \ Plain film	Nodular		Reticular	Ring	
	≦2 mm	2 mm<		≦5 mm	5 mm<
Obstruction	4 (5)	1 (2)	2 (4)	5 (11)	1 (2)
Dilatation	3 (5)	1 (2)	2 (4)	4 (10)	1 (2)
Narrowing	7 (13)	1 (2)	3 (7)	4 (8)	0 (0)
Poor branching	8 (10)	1 (2)	5 (9)	7 (14)	1 (2)
Tortuosity	2 (3)	0 (0)	0 (0)	1 (1)	1 (1)
Alveolar ductectasis	7 (10)	1 (1)	4 (8)	6 (10)	1 (2)
Alveolar uneven filling	3 (5)	1 (1)	3 (3)	4 (5)	1 (1)
Alveolar abnormal figure	4 (6)	1 (2)	5 (8)	4 (6)	1 (2)

$\frac{\text{case}}{\text{(score)}}$ • The score is the product of (grade of SAB findings) × (total of case)

less than 2 mm on plain chest X-ray frequently showed narrowing of the bronchioles, poor branching, and alveolar uneven filling. When abnormal findings in plain chest X-ray films were more marked, they were associated with findings of dilatation and obstruction on SAB.

2) Findings on Various X-ray Examinations and Pulmonary Function Tests

When findings on plain chest X-ray were compared with %VC, $FEV_{1.0}$% and $\dot{V}_{25}$, (Table 5) (Table 6) normal %VC and $FEV_{1.0}$% were associated with most cases of nodular shadows of less than 2 mm, and abnormal %VC and $FEV_{1.0}$% were associated with most cases of nodular shadows of 2 mm or more, reticular

Table 5 Chest X-ray findings and pulmonary function test

N=26

Plain film		%VC		$FEV_{1.0}$%	
		Normal	Abnormal	Normal	Abnormal
Nodular	≦2mm	8	2	7	3
	2mm<	0	2	0	2
Reticular		3	4	4	3
Ring	≦5mm	2	5	1	6
	5mm<	0	1	0	1

Table 6 Chest X-ray findings and pulmonary function test

N=16

Plain film		$\dot{V}_{25}$	
		Normal	Abnormal
Normal		5	2
Nodular	≦2mm	1	5
	2mm<	0	0
Reticular		1	1
Ring	≦5mm	0	1
	5mm<	0	0

Table 7 SAB findings and pulmonary function test

N=34

SAB	%VC		$FEV_{1.0}$%	
	Normal	Abnormal	Normal	Abnormal
Poor branching	14 (70.0%)	12 (85.7%)	12 (63.2%)	14 (93.3%)
Alveolar uneven filling	11 (55.0%)	12 (85.7%)	10 (52.6%)	13 (86.7%)
Narrowing	11 (55.0%)	8 (57.1%)	9 (47.4%)	10 (66.7%)
Alveolar Ductectasis	9 (45.0%)	8 (57.1%)	9 (47.4%)	8 (53.3%)
Obstruction	6 (30.0%)	9 (64.3%)	7 (36.8%)	8 (53.3%)
Total	20	14	19	15

shadows, or ring-like shadows of less than 5mm. Most patients without abnormal findings on chest X-ray had a normal $\dot{V}_{25}$, and abnormal $\dot{V}_{25}$ became frequent with the appearance of nodular shadows of less than 2mm.

%VC, $FEV_{1.0}$% and $\dot{V}_{25}$ were normal in 48.1%, 44.4% and 43.7% of the subjects, respectively.

When findings on SAB were compared with %VC, $FEV_{1.0}$% and $\dot{V}_{25}$, (Table 7) (Table 8) patients with normal %VC frequently showed poor branching, followed by other comparatively common findings, i.e., alveolar uneven filling, narrowing, alveolar duct ectasis, and obstruction. Abnormal %VC, $FEV_{1.0}$% and $\dot{V}_{25}$ were frequently associated with poor branching and alveolar uneven filling, followed by obstruction, narrowing and alveolar duct ectasis.

Table 8　SAB findings and pulmonary function test

N=16

SAB	$\dot{V}_{25}$	
	Normal	Abnormal
Poor branching	5 (71.4%)	5 (55.6%)
Alveolar uneven filling	4 (57.1%)	4 (44.4%)
Narrowing	4 (57.1%)	4 (44.4%)
Obstruction	2 (28.6%)	3 (33.3%)
Dilatation	1 (14.3%)	3 (33.3%)
Total	7	9

Table 9　Scores of SAB findings

N=33

SAB \ Grade	0	1	2	3	case (score)
Obstruction	18 (0)	7 (7)	5 (10)	3 (9)	15 (26)
Dilatation	22 (0)	1 (1)	7 (14)	3 (9)	11 (24)
Narrowing	15 (0)	3 (3)	14 (28)	1 (3)	18 (34)
Poor branching	7 (0)	15 (15)	7 (14)	4 (12)	26 (41)
Tortuosity	28 (0)	3 (3)	2 (4)	0 (0)	5 (7)
Alveolar ductectasis	10 (0)	10 (10)	12 (24)	1 (3)	23 (37)
Alveolar uneven filling	19 (0)	11 (11)	2 (4)	1 (3)	14 (18)
Alveolar abnormal figure	16 (0)	9 (9)	7 (14)	1 (3)	17 (26)

The score is the product of (grade of SAB findings) × (total of case)

In cases of normal $FEV_{1.0}$%, poor branching, alveolar uneven filling, narrowing and alveolar duct ectasis were comparatively common, followed by obstruction. Cases of abnormal $FEV_{1.0}$% frequently showed poor branching and alveolar uneven filling, followed by narrowing, alveolar duct ectasis, and obstruction. Normal $\dot{V}_{25}$ was frequently associated with poor branching, alveolar uneven filling and narrowing, followed by obstruction and dilatation. In cases of abnormal $\dot{V}_{25}$, poor branching, alveolar uneven filling, narrowing, obstruction and dilatation were found comparatively evenly. As a result, there was no correlation between SAB findings and %VC, $FEV_{1.0}$% and $\dot{V}_{25}$ in our patients.

Discussion

Reports of bronchiolitis have increased since Lange (1901)[14] reported an autopsied cases of obstructive

bronchiolitis and Frankel (1902) a clinical case of this condition due to inhalation of fumes of nitrates. LaDue (1941)[15] made a general classification of the possible causes of this condition, and McAdams (1955)[16] stressed that nitric oxide gas as an irritant gas can easily cause bronchiolitis. After that, since the proposal of the concept of small airway disease[17)20)21], the pathological condition of the peripheral airway[18)19] and diffuse panbronchiolitis[22] has been drawing attention. Now, bronchiolitis is regarded as an independent disease and, therefore, there is a great need for the development of a method for understanding the lesions of bronchiolitis.

As methods of respiratory physiological diagnosis[1)~6], assessments of flow-volume curve, closing volume, pulmonary gas distribution by single-breath washout, frequency dependence of dynamic compliance, and alveolar-arterial O_2 tension difference ($AaDo_2$) have been considered. However, it is difficult to diagnose this condition by the above examinations alone. Therefore, morphological diagnosis is definitely required.

The findings of this disease on plain chest X-ray have been characterized by reticular and nodular shadows, which closely resemble those in miliary tuberculosis. When our patients were examined, most showed diffuse scattered nodular shadows of less than 2 mm and reticular shadows but did not have any obviously abnormal shadows in the lung field. This finding is consistent with previous reports, excluding the fact that no abnormal shadows were observed in the lung field. The distribution density of abnormal shadows ranged rather evenly from low to high. The extent of abnormal shadows was one third of the entire lung field in many patients (44%). It is distinctive in this disease that a comparatively great proportion of patients, 26.5%, show no abnormality on plain chest X-ray during inspiration.

Abnormal shadows in lesions in the peripheral airway are caused according to 1) to extent of the distribution density of the lesion, 2) the air volume caused by air trapping, 3) the degree of change in the surrounding lung parenchyma caused by the extending lesion, and 4) the degree of retention of sputum. Overlap of three or more shadows representing lesions on irradiation is necessary to form a nodular shadow or a fine ring-like shadow. Nodular shadows represent intraalveolar or interstitial change, and fine ring-like shadows represent change in the interstitium or the alveolar septa. A lesion in the peripheral airway, whose wall is thin, will easily extend to the whole bronchial tissue. The peripheral airway is liable to be obstructed by change in surfactants and retention of secretion because the lumen is narrow.

Plain chest X-ray is not a sensitive examination for this disease. In early detection of this disease, it is necessary to understand the lesion before diffuse shadows appear in the lung field. Of six patients without abnormal shadows on chest X-ray during inspiration, five showed abnormal shadows on chest X-ray during expiration. This indicates that chest X-ray both during inspiration and during expiration is essential for diagnosis of suspected cases of this disease.

Magnification radiography revealed abnormal shadows in two of four patients who exhibited no abnormal shadows on chest X-ray druing inspiration. It may also be necessary to perform this examination together with chest X-ray during expiration, when there is no abnormal shadow in chest X-ray films during inspiration.

SAB findings of this disease (Table 9), which are comparatively in great variety, are chiefly poor branching, alveolar uneven filling, and narrowing. The high incidence of poor branching may be attributable to embolus, stenosis and obstruction by secretion in the lumen. Uneven ventilation in the bronchiolar and alveolar regions seems to underlie the high incidence of alveolar uneven filling.

When findings on plain chest X-ray and SAB were compared, patients whose chest X-ray films showed nodular shadows of less than 2 mm frequently showed narrowing and poor branching of the bronchioles and alveolar uneven filling. These findings came to be accompanied by dilatation and obstruction when abnormal shadows in chest X-ray films became more marked.

Morphological classification of SAB findings of this disease is represented by a group with narrowing of the terminal bronchioles, in which narrowing of the bronchioles from the respiratory to the terminal bron-

chioles is predominant, and a group with dilatation of the terminal bronchioles, in which dilatation extending from the respiratory bronchioles to the alveoli is predominant.

When ventilatory function and plain chest X-ray films were compared, it was found that plain chest X-ray films with a mild abnormality, i.e., nodular shadows of less than 2 mm, were frequently associated with normal values of %VC and $FEV_{1.0}$%, and the incidence of abnormal values became higher when abnormality in chest X-ray films was more severe. The plain chest X-ray film was usually normal when $\dot{V}_{25}$ was normal. The incidence of abnormal values of $\dot{V}_{25}$ increases when nodular shadows of less than 2 mm appeared in the chest X-ray film. There was no significant relationship between the findings of spirometry and SAB.

Accoring to our study on the relationship between infection and SAB findings of the bronchioles, most case suggestive of coexistence of airway infection were classified into the group with dilatation of the terminal bronchioles, while most of those without infection were classified into the group with narrowing of the terminal bronchioles. Thus, it is suggested that airway infection plays some role in dilatation of the bronchioles.

Conclusion

1) When the patient is examined on plain chest X-ray, films during both inspiration and expiration should be taken.

2) Comparatively many cases of his disease show no abnormality on plain chest X-ray during inspiration. As abnormal shadows, nodular shadows of less than 2 mm and reticular shadows are rather characteristic of this disease.

3) Patients with this disease who have shown nodular shadows of less than 2 mm or plain chest X-ray frequently reveal narrowing, poor branching and alveolar uneven filling on SAB. The more marked abnormality on chest X-ray, the more frequent the findings of dilatation and obstruction.

4) A group with narrowing of the terminal bronchioles (Type I) and another with dilatation of the terminal bronchioles (Type II) are predominant in cases of this disease.

5) Normal %VC and $FEV_{1.0}$% were associated with most cases of nodular shadows of less than 2 mm. Abnormal %VC and $FEV_{1.0}$% were associated with most cases of nodular shadows of 2 mm or more, reticular shadows, ring-like shadows of less than 5 mm.

6) Most cases without abnormal findings on chest X-ray had a normal $\dot{V}_{25}$, and abnomal $\dot{V}_{25}$ became frequent with the appearance of nodular shadows of less than 2 mm.

7) There was no correlation between SAB findings and %VC, $FEV_{1.0}$% and $\dot{V}_{25}$ in our cases.

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