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Roentgenological Evaluation of the Loss of Pulmonary Vascular Definitions for the Early Detection of Interstitial pulmonary Edema and Other Interstitial Pulmonary Diseases

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Accumulation of fluid was done in the peri-vascular interstitium of dogs by abundant and rapid saline infusion, and chest roentgenograms and tomograms were taken and the lung was examined histologically.

Post-infusion roentgenograms characteristically demonstrated a blurred outline of vascular shadows without observable abnormal densities instead of the sharp outline which appeared in the pre-infusion roentgenograms.

This finding may contribute to the early detection of interstitial pulmonary edema because it preceded the Kerley lines and abnormal densities in the lung field.

This peri-vascular interstitial condition may be roentgenologically substituted for other kinds of lesions. Thus the loss of vascular definition may lead to the early diagnosis of certain interstitial pulmonary diseases.

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1 Introduction

The lung possesses characteristic roentgenological organ features such as the parenchyma, the interstitium, and air in the alveolar spaces.

Parenchymal diseases may be identified easily as abnormal shadows on chest roentgenograms because the intraalveolar air is replaced by exudative fluid which contributes to increased X-ray attenuation.

On the other hand, interstitial diseases are not readily observed as abnormal shadows especially in the early stage as these lesions produce very subtle densities. This might explain partly the delayed diagnosis of some interstitial pulmonary diseases.

It is known that in pulmonary edema, peri-vascular and bronchial interstitial edema precedes alveolar ones[1~4]. Furthermore, we believe that some interstitial pulmonary diseases start with lesions in the same area.

In this study, experimental fluid accumulations were performed in the perivascular interstitium of dogs and were roentgenologically analysed with a focus on the changes in the appearance of vascular outlines, not on the abnormal shadows.

The roentgen findings were then compared with Kerley lines, the most familiar sign of interstitial pulmonary edema, in order to determine the earlier sign of the disease.

2. Materials and Methods

Five adult mongrel dogs weighing 16.0 to 40.0 kg were anesthesized intravenously with ketamine HCl and intubated and ventilated with room air.

A left femoral arterial cannula was inserted to monitor pressure, and a bilateral femoral venous cannula was inserted for the saline infusions. Another cannula was inserted via the left jugular vein into the left pulmonary artery to monitor the pulmonary arterial pressure.

Abundant saline was infused rapidly until the pulmonary vascular definition became indistinct in the routine anteroposterior (AP) chest roentgenograms.

Routine AP chest roentgenograms and tomograms were taken before and after the infusion by an HL5, Shimazu, Tokyo, Japan (Table 1 a, b).

Table 1 a *Exposure conditions for routine roentgenography*

Case No.	Position	kVp	mAS	FFD	Film	Screen	Grid
1	Anteroposterior	70	6	150 cm	Sakura A	Hi-screen (Fuji)	Grid
2	Anteroposterior	82	8	150 cm	Sakura A	Hi-screen (Fuji)	Grid
3	Anteroposterior	72	6	150 cm	Sakura A	Hi-screen (Fuji)	Grid
4	Anteroposterior	70	6	150 cm	Sakura A	Hi-screen (Fuji)	Grid
5	Anteroposterior	74	6	150 cm	Sakura A	Hi-screen (Fuji)	Grid

Table 1 b *Exposure conditions for tomography*

Case No.	Position	kVp	mAS	FFD	Film	Screen	Grid	Exposure angle	Section interval
1	Anteroposterior	70	14	150 cm	Sakura A	Hi-screen (Fuji)	Grid	45°	1.0 cm
2	Anteroposterior	80	14	150 cm	Sakura A	Hi-screen (Fuji)	Grid	45°	1.0 cm
3	Anteroposterior	72	14	150 cm	Sakura A	Hi-screen (Fuji)	Grid	45°	1.0 cm
4	Anteroposterior	70	14	150 cm	Sakura A	Hi-screen (Fuji)	Grid	45°	1.0 cm
5	Anteroposterior	74	14	150 cm	Sakura A	Hi-screen (Fuji)	Grid	45°	1.0 cm

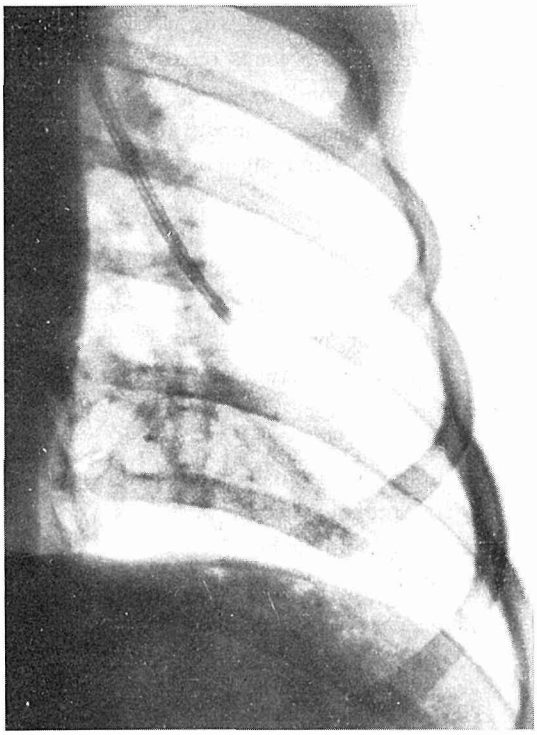

Fig. 1 a Pre-infusion routine AP chest roentgenogram. Vascular outlines are sharply delineated.

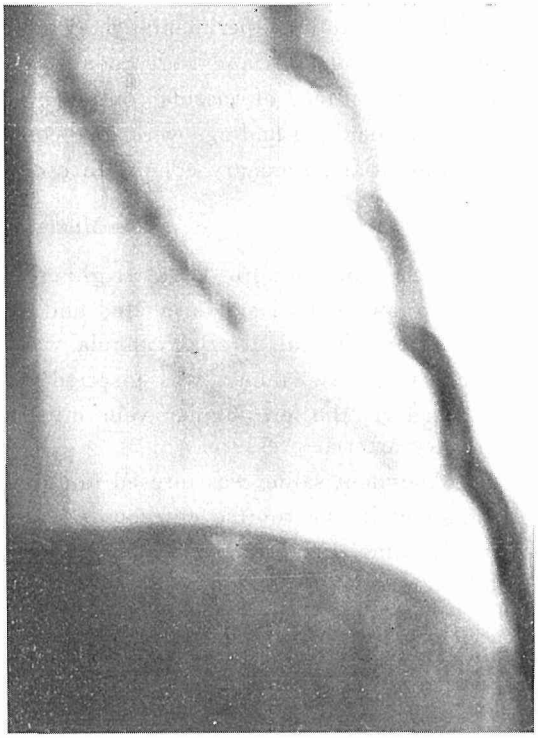

Fig. 1 b Pre-infusion chest tomogram showing clearly marginated vascular shadows in greater detail.

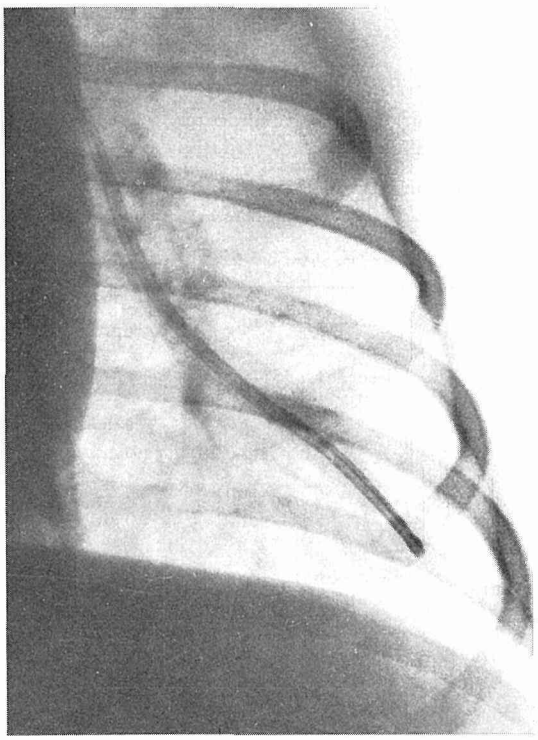

Fig. 2 a Post-infusion routine AP chest roentgenogram. Vascular outlines are indistinct. Kerley lines and subpleural thickening are not observed.

Fig. 2 b Post-infusion chest tomogram. Vascular definitions are blurred. Subtle and soft densities are observed along these structures.

Then, a non-selective pulmonary angiography was performed by inserting a 10.0 cm length catheter with an inside diameter of 3.5 mm into the left jugular vein and injecting iodamide sodium meglumine, 80 w/v%, 1.0 m*l*/kg, in 2.0 sec.

The animals were then sacrificed for the histological examination.

3 Results

The pre-infusion AP chest roentgenogram (Fig. 1 a) revealed well marginated

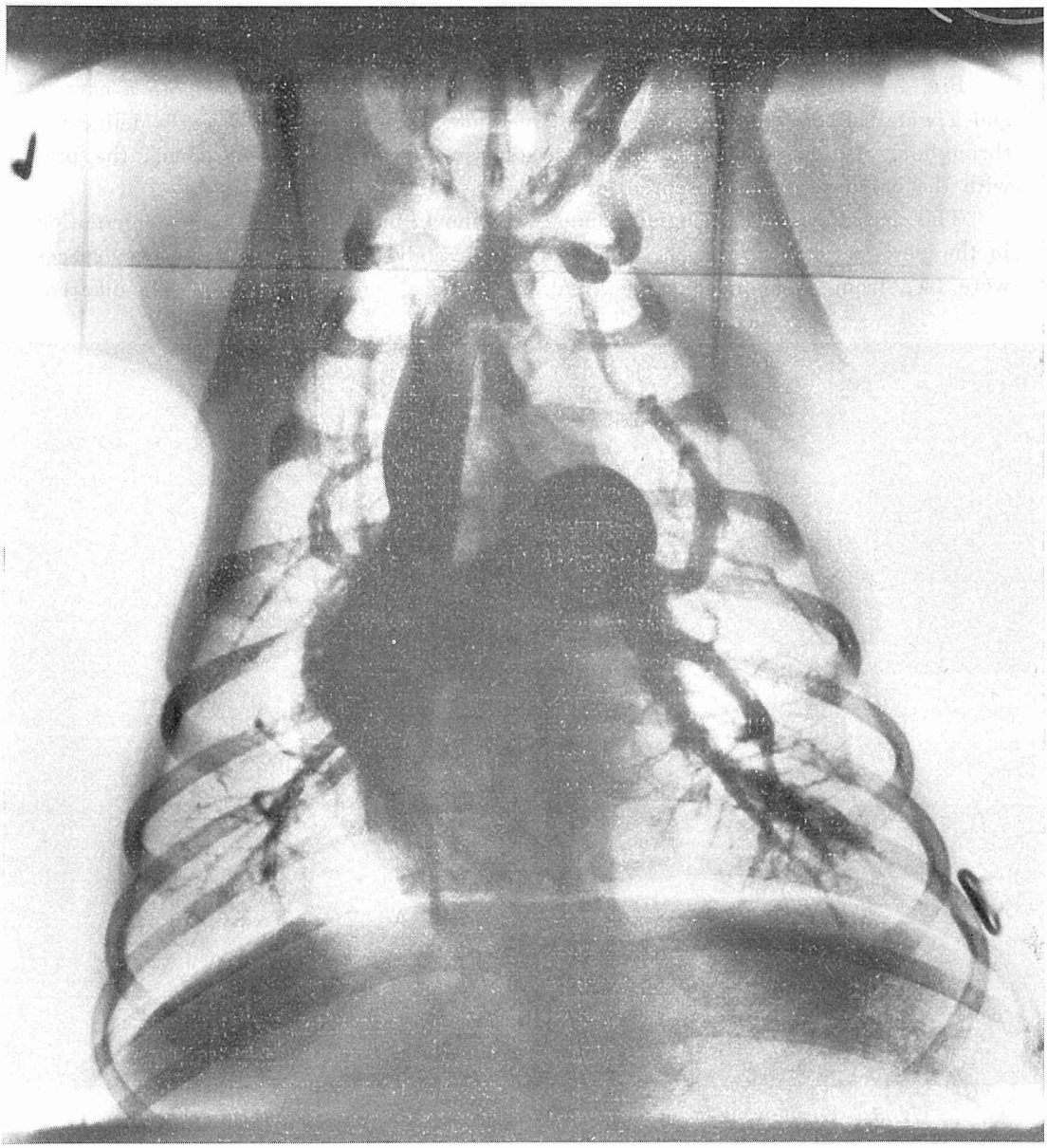

Fig. 3 Post-infusion non-selective pulmonary angiogram, arterial phase.

vascular silhouettes. The tomograms (Fig. 1 b) taken at the same time expressed these vascular shadows in greater detail.

In Fig. 2 a, the post-infusion AP chest roentgenogram showed blurred outlines instead of the distinct vascular shadows which appeared in Fig. 1. The Kerley lines, the most familiar sign of interstitial pulmonary edema, and subpleural thickening were not observed. Even the tomogram (Fig. 2 b) failed to disclose the vascular definitions; instead subtle and soft densities were observed along these structures.

The post-infusion non-selective pulmonary angiogram (Fig. 3) demonstrated pulmonary arteries with a monopodium branching pattern. The arteries were thought to be slightly decreased in diameter.

Fig. 4 is the roentgenogram of a glass tube model consisting of both a narrow and a wide caliber containing a contrast medium. The outline was clearly delineated throughout the overall length, although different densities were observed; the part with the narrow caliber presented lower densities than the wide part.

The characteristic histologic findings were shown in Fig. 5, i. e., fluid accumulation in the periarterial interstitium. The surrounding alveolar septa and alveolar spaces were free from edematous changes and presented a normal arpearance. In different

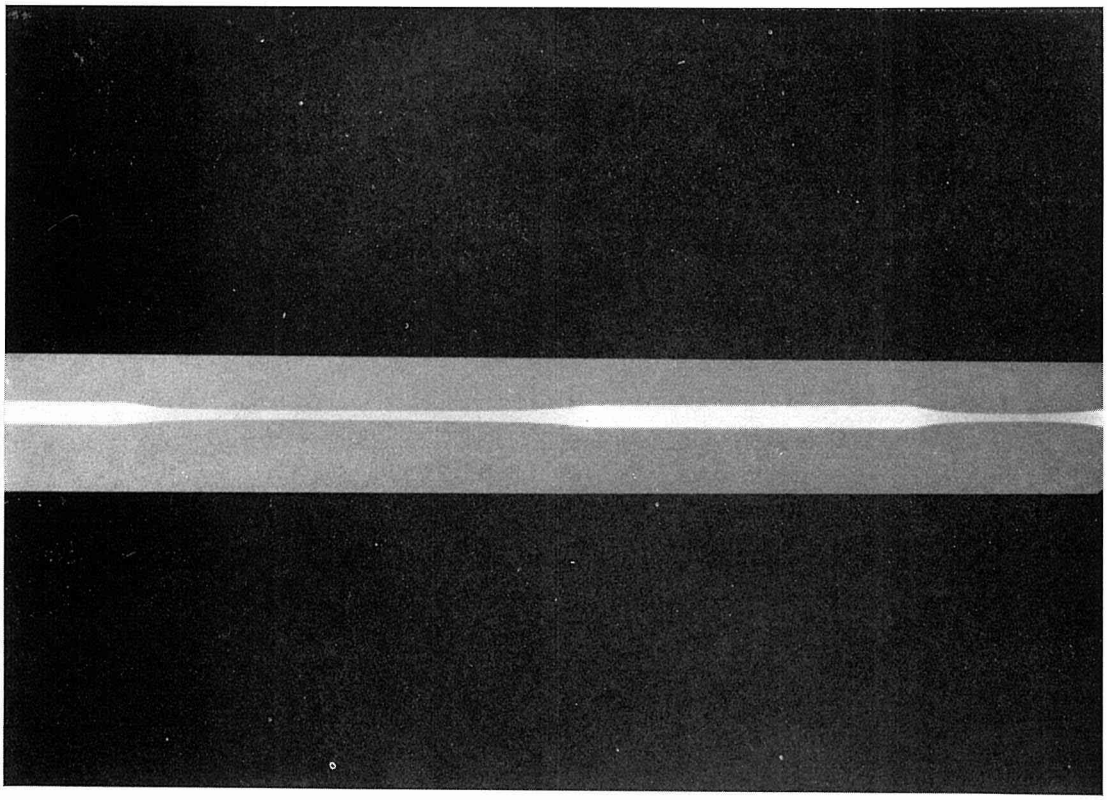

Fig. 4 Roentgneogram of a glass tube model. The outline is clearly delineated throughout the overall length, although the part with the narrow caliber presents lower densities than the wide part.

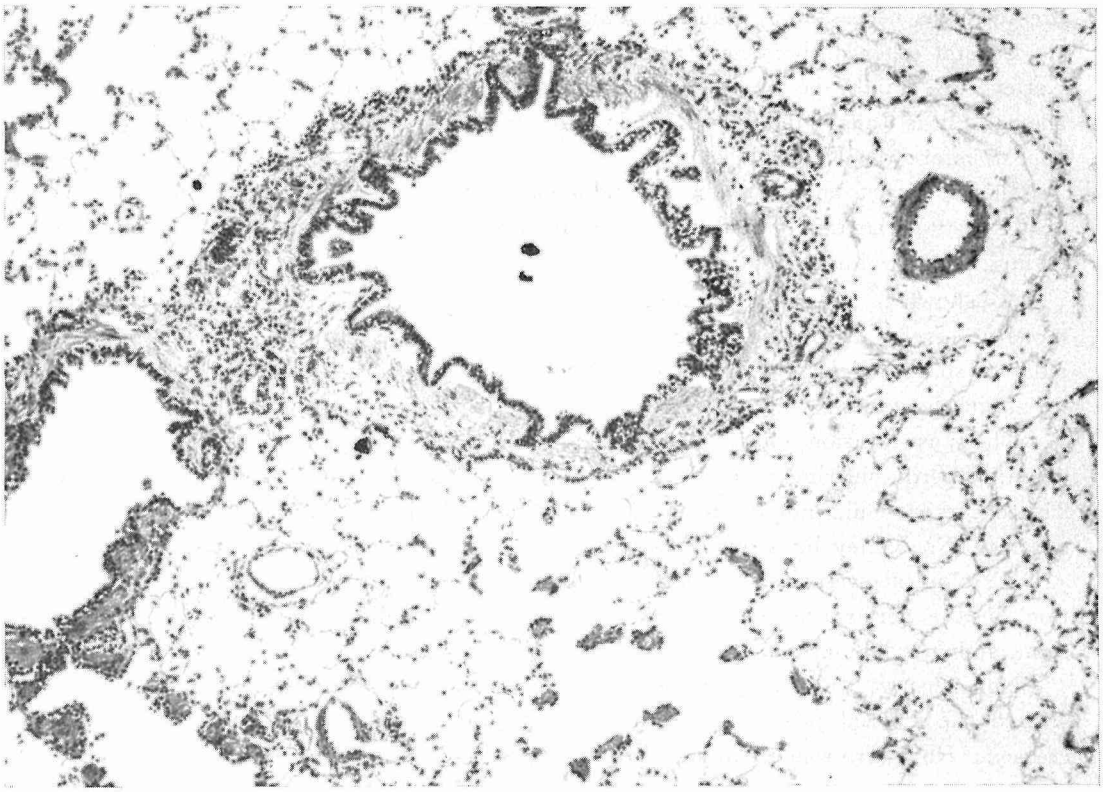

Fig. 5 Fluid accumulation in the periarterial interstitium. The surrounding alveolar septa and alveolar spaces are normal.

fields, the same findings, although to a lesser degree, were obtained in the peri-venous and bronchial interstitium.

The interlobular septa were not thickend.

4 Discussion

Chest roentgenograms are usually initially used to determine clinically the presence of the abnormal increase of pulmonary extravascular fluid and to measure its volume. Our clinical experiences have verified the usefulness of this method for the diagnosis of pulmonary edema when it progressed to the stage in which the intraalveolar fluid is produced. However, the roentgenogram has been limited as a method for early stage detection in the case of interstitial pulmonary edema. The reported roentgen signs of interstitial pulmonary edema include the Kerley lines[4,5] which are represented as thickened interlobular septa.

McGreide[6] estimated the pulmonary extravascular fluid volume in a group of patients with mitral and aortic valvular diseases by using a double isotope dilution technique. Eighteen patients showed abnormally higher values than the normal range $-62 \sim 152$ ml/m^2 (107 ± 2 S. D.) and only seven out of them demonstrated the Kerley lines.

Grainger[7] reported that at least twice or three times elevation of the left atrial

pressure was necessary for the appearance of Kerley lines.

Several other authors have also published pessimistic reports indicating that the Kerley lines might be of little use for the early detection of pulmonary interstitial edema. It is thus important to isolate other roentgen signs of the disease which appear before the Kerley lines.

In his report on saline loaded pulmonary edema in dogs, Wakahama *et al.*[8] reported that periarterial fluids quantitatively increased corresponding to the increment of lung water volume.

As shown in the pre-infusion chest roentgenogram (Fig. 1), medium-large sized pulmonary vessels, either arteries or veins, are normally seen either end on or longitudinally as sharply defined columns of soft-tissue density, and they are clearly outlined by air in the surrounding alveolar spaces.

The post-infusion chest roentgenogram (Fig. 2 a) revealed the loss of vascular definition with blurring of the outline. However, these changes were so subtle (Fig. 2 b) that they could not be detected as abnormal shadows in routine chest roentgenograms. No Kerley lines were observed.

Histological evaluation of these characteristics consistently showed fluid accumulation, in the periarterial interstitium and more specifically, alveolar spaces, alveolar septa and interlobular septa were free of edematous changes.

Non-selective pulmonary angiograms performed after saline load (Fig. 3) demonstrated the arterial phase. Here the arterial caliber was thought to be slightly decreased. However, roentgenograms of the glass tube model containing the contrast medium (Fig. 4) clearly demonstrated that the smaller diameter tubes (vessels) had no effect on the sharpness of the outline, but they had an effect only on its density, which resulted from the lower X-ray attenuation.

We concluded that fluid accumulation in the peri-pulmonary vascular interstitium alone tends to blur roentgenologically the normally sharp outline of the pulmonary vessels without the surrounding alveolar septal and alveolar edema. However, because these subtle densities result from the minimum changes and the tendency of the disease to spread along the interstitium, they are unobservable as abnormal shadows in routine chest roentgenograms. We believe that this loss of vascular definitions may be a significant roentgen sign of early interstitial pulmonary edema because it preceded the Kerley lines.

Theoretically and by extension, these edematous changes can be roentgenologically substituted for other lesions in the perivascular interstitium, including acute inflammatory cellular infiltrations, fibrosis, lymphangiosis carcinomatosa[9], etc. Thus this sign may also lead to the early diagnosis of certain interstitial pulmonary diseases.

Acknowledgment

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肺血管影辺縁の不鮮明化像のレ線学的検討

——間質性肺水腫およびその他の間質性肺疾患の早期発見のために——

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成犬を用い急速大量生食水負荷により，血管周囲間質浮腫を作成し，負荷前後の胸部単純および断層像撮影を行い，その組織像と比較検討を行った．

生食水負荷の胸部レ線像によると異常影は認め難いが，負荷前には鮮明であった肺血管影の辺縁は不鮮明となった．組織像によると血管周囲間質浮腫は認めるが，周囲の肺胞腔，肺胞中隔は正常であり，血管周囲間質病変のみにより肺血管影が不鮮明になったと考えられる．

このレ線像は，間質性肺水腫のレ線像として最も良く知られている Kerley line および肺野の異常影に先行し，その早期発見に重要であると考えられる．

血管周囲間質浮腫は，レ線学的にその他諸種の血管周囲間質病変と置換される．したがってこのレ線像は，諸種の間質性肺疾病の早期発見，治療および急性～慢性病態解析の出発点ともなる重要な所見であると考える．