Pediatr Radiol (1988) 18: 194-199

Pediatric Radiology

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Pulmonary interstitial emphysema - a radiological and pathological correlation

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Abstract. The pathology and radiology of 19 cases of histologically proven pulmonary interstitial emphysema (PIE) were studied retrospectively. There was a good correlation between the pathological and radiological findings. Radiology therefore provides a useful indicator of early PIE which may allow more successful management and decreased morbidity and mortality.

Pulmonary interstitial emphysema (PIE) is a serious complication of hyaline membrane disease, which has become more common with the improved survival rate of very premature babies in present day neonatal intensive care units.

PIE, as manifested by gas within the lymphatics of the peribronchovascular sheaths, interlobular septa and visceral pleura has been well recognised pathologically and was first described by Laennec

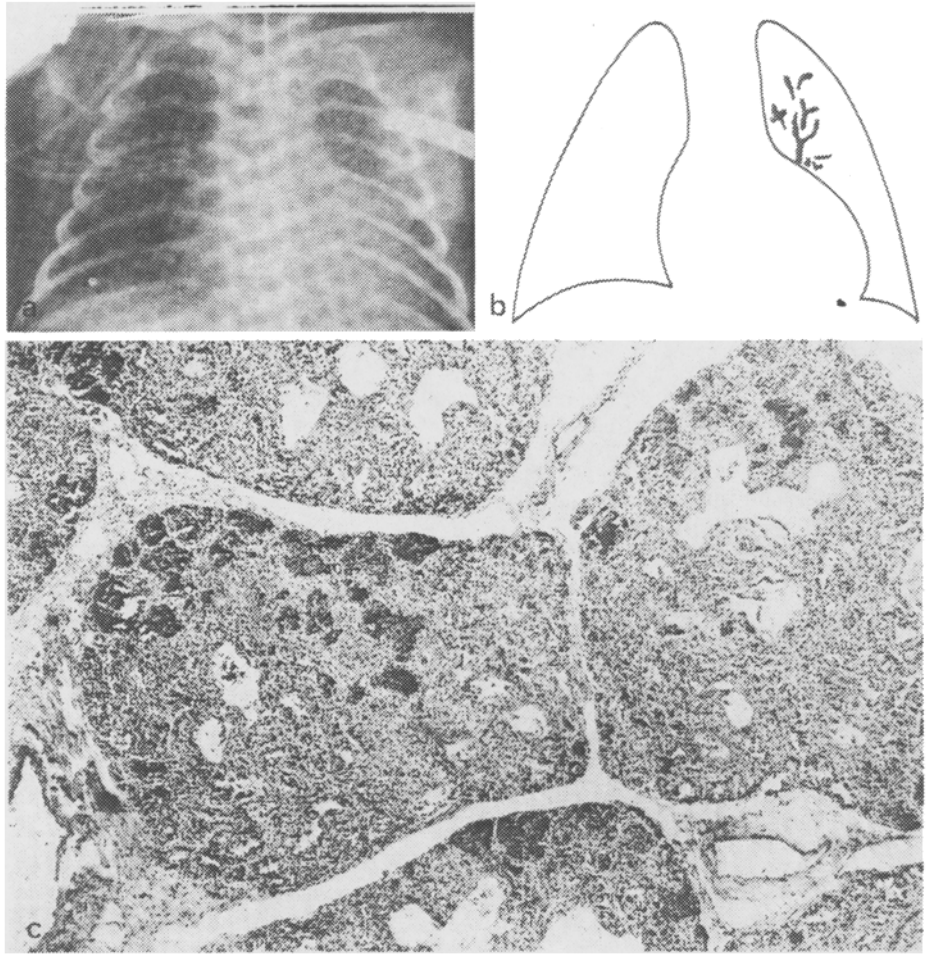


Fig. 1 a and b. Grade I: Cystic and linear translucencies are seen in the left upper zone. c Grade I: Minimal gaseous distention of the interlobular and perivascular lymphatics. H and E × 36

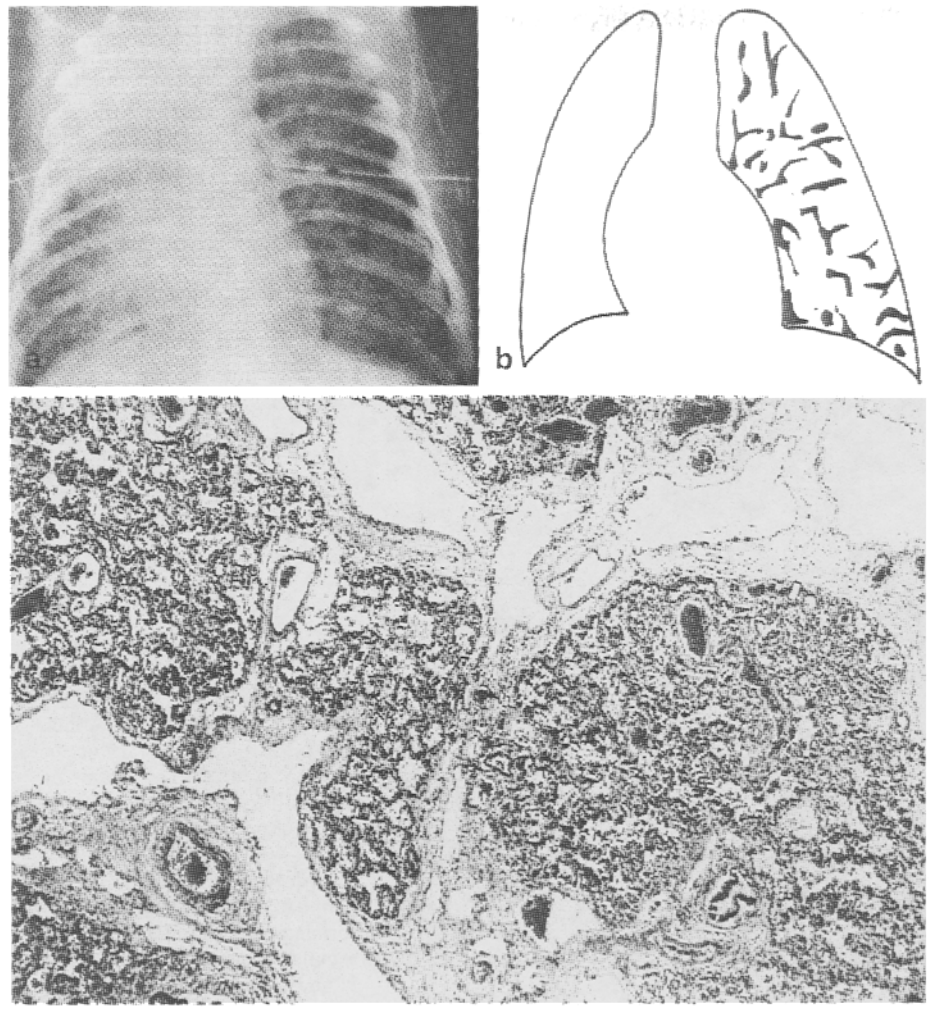


Fig. 2 a and b. Grade II: Tubular branching pattern of distended lymphatics is seen particularly in the left lung. **c** Grade II: Moderate gaseous distension of the pulmonary lymphatics. H & E × 36

in 1837 [1]. The finding was a curiosity and of little clinical interest until the intensive management of neonatal respiratory problems became a reality. The syndrome has been given many diverse names including intrapulmonary interstitial pneumatosis and air-block syndrome. The radiological appearances were first described by Prosser [2] and subsequently by other authors [3]. There are fewer accounts of the comparable pathological changes but a good description has been given by Burnard [4].

Method

A retrospective analysis of all the post-mortems reporting lymphatic gas at St. Mary's Hospital, Manchester during a 3-year period was carried out and the corresponding radiographs taken were traced. A total of 25 post-mortem diagnoses of lymphatic gas were made and the radiographs (AP, supine and mobile) of 19 cases were obtained. All the neonates with one notable exception, a stillborn, had been ventilated and all were premature.

The radiological appearances of lymphatic gas may change rapidly and therefore the appearances of the last antemortem radiograph were assessed and compared with the post-mortem findings. The last radiograph was usually taken during final resuscitative attempts and all were taken within 1 h of death. Both the X-ray and post-mortem findings were graded (I-III) independently by a radiologist and pathologist according to severity. The grading system was deliberately kept simple since this was essentially a subjective assessment.

Grade I: This was characterised by several cystic gas spaces in the lung periphery which did not conform to the bronchial tree (Figs. 1 a, b). Histologically the mildest degree of PIE is illustrated (Fig. 1 c) where there is minimal gaseous distention of the perivascular and interlobular lymphatics.

Grade II: Here the radiographs showed a more widespread tubular branching pattern (Figs. 2 a, b). Histologically this grade required an obvious dilatation of the lymphatics to a diameter that increased the normal width of the interlobular septae (Fig. 2 c).

Grade III: This corresponded radiologically to the presence of grossly abnormal cystic and tubular structures, often causing an increase in the volume of the affected area of lung (Figs. 3 a, b). The most severe histological grade required extreme gaseous distension of the lymphatics so that they assumed a balloon-like appearance several times their normal diameters (Fig. 3 c). Such lymphatics could usually be traced at low magnification from the hila to the periphery of the lungs along distorted interlobular septae.

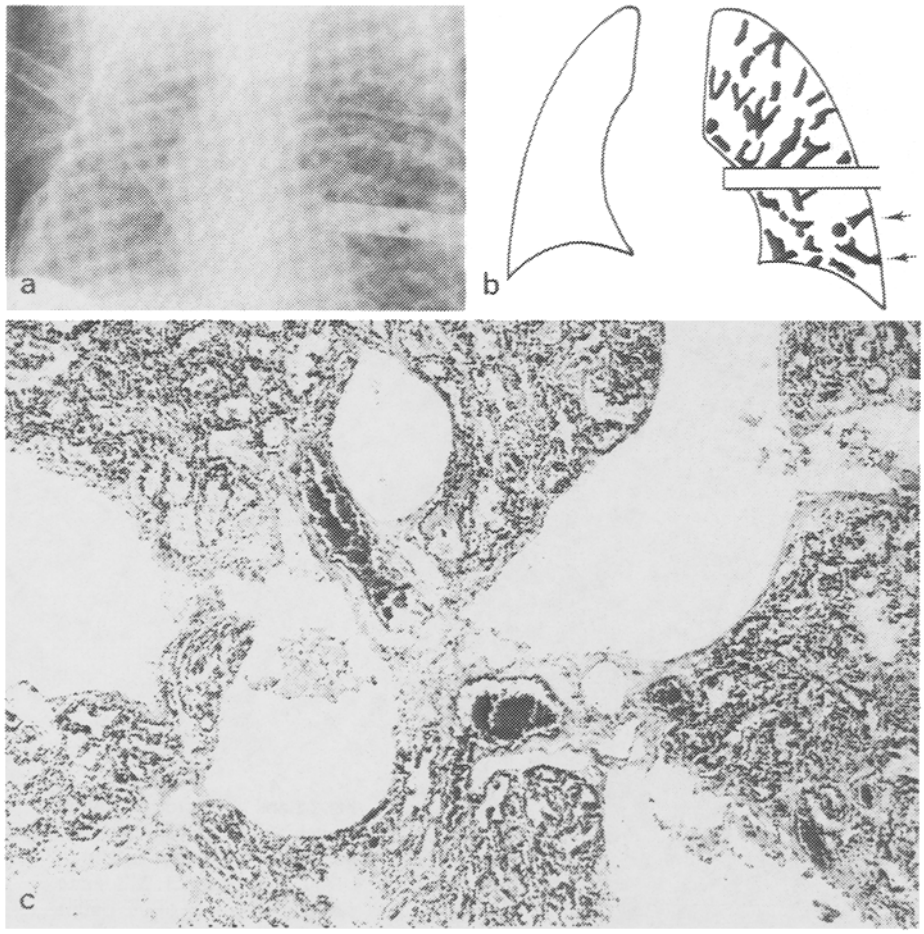


Fig. 3a and b. Grade III: Abnormal cystic and linear translucencies causing an increase in volume of the left lung. The translucencies arrowed correspond to 'negative' Kerley B lines. **c** Grade III: Gross over-distension of the pulmonary lymphatics by gas, characteristically forming three irradiating spaces around a pulmonary blood vessel. H and E × 36

Results

The radiological features of PIE were essentially similar to those described by Campbell [3]. The lymphatic gas had a disorganised, haphazard distribution throughout the lungs which did not conform to the anatomical pattern of an air bronchogram. These abnormal gas collections were both linear and cystic. The linear spaces seldom exceeded 2 mm in width and extended in a coarse, non-branching pattern from the hila to the periphery of the lungs. The cyst-like radiolucencies ranged from 1 to 4 mm in diameter and although usually rounded did assume ovoid or lobulated shapes.

These radiological features are illustrated alongside their apparent histological counterparts in Figures 1-3. Although the lungs showed a wide spectrum of histopathology depending on the degree, duration and complications of hyaline membrane disease, they all had in common a variable distention of the collecting lymphatic vessels within the interlobular and perivascular connective tissues. In the most severe examples medium sized branches of the pulmonary arteries were ensheathed by hugely dilated lymphatic air spaces which occasionally even compressed them (Fig. 4).

Haemorrhage into the interstitial connective tissue of the lung is a characteristic of profound hypoxia in infancy. In three cases where this had happened distended lymphatics had been filled with blood, probably as a terminal event secondary to previous gaseous distension (Fig. 5a). The chest radiograph (Fig. 5b) of this case shows non-specific deaeration in the lung periphery corresponding with the areas of haemorrhage seen on histology.

A comparison of the radiological and pathological grading used in this survey is shown on Table 1. It can be seen that 14 of the 19 cases have identical radiological and pathological gradings. This is statistically significant despite the small sample size (Spearman correlation coefficient = 0.66). The method of grading adopted therefore seems to indicate that the comparison of the radiological and histopathological features illustrated in Figures 1 to 3 is sufficiently accurate for clinical purposes.

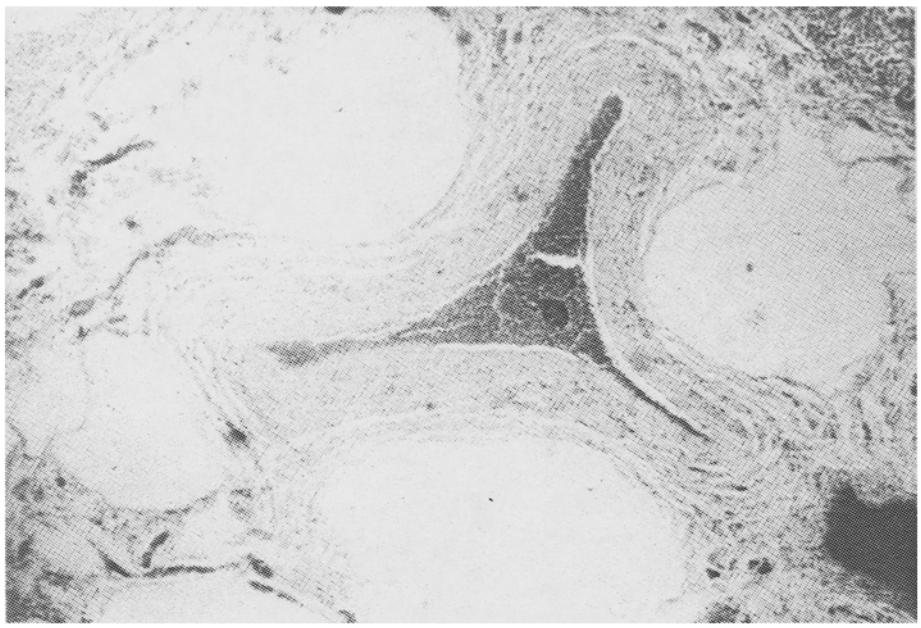


Fig. 4. Compression of a pulmonary arteriole by three distorted lymphatic channels. H and E × 36

Discussion

Twenty-four of the 25 infants in this study who had gaseous distention of the pulmonary lymphatics at post-mortem examination had had positive pressure ventilation during life. The remaining case was a single stillborn infant on whom ventilation had been performed in order to train medical staff in the technique of resuscitation of the newborn. Of the 19 cases where antemortem radiographs were available there was good correlation of the antemortem and postmortem morphology.

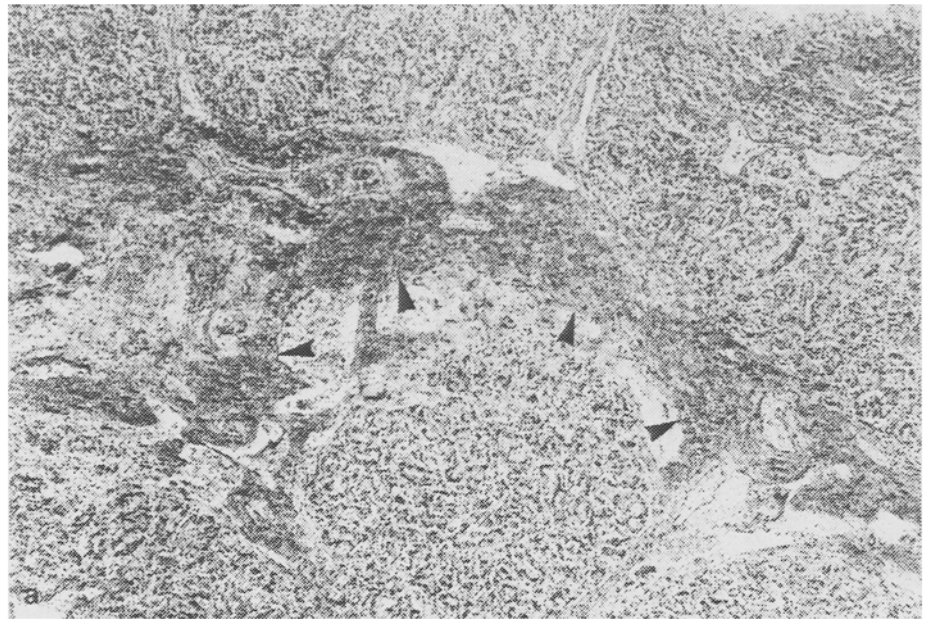
Barotrauma has been recognised as a cause of interstitial emphysema since it was first induced experimentally by Kelmann in 1919 [5]. It has also become clear that the extent of PIE increases with the pressures adopted for ventilation of the neonate [6].

Although the role of barotrauma in causing PIE is accepted not all investigators have appreciated that gas accumulates within the lymphatic system of the lungs rather than dissecting through supposedly artificial channels in pulmonary interstitial tissue around blood vessels [7]. Involvement of the lymphatics is an essential element of the pathogenesis of the condition but the precise portal of entry of gas has never been clearly demonstrated.

Thibeault et al. [8] noted that interstitial emphysema predominated in premature infants and was often complicated by pneumothorax and/or pneumomediastinum. In term babies pneumothorax and pneumomediatinum tended to occur without radiologically detectable interstitial gas. Plenat et al. [9] explained this on the basis of a looser texture of the interstitial tissue of the premature infant allowing gas to accumulate at lower pressures than in a term infant. This finding correlates well with the embryology of the pulmonary lymphatic system. Prior to 7 months gestation there are no competent valves in the pulmonary lymphatics [10], and pooling of lymph within these vessels is seen until the lymphatic valves are properly developed. It seems reasonable to deduce that immature incompetent lymphatic valves predispose the ventilated premature infant to the gaseous distention of the lymphatics which is characteristic of PIE.

The early detection of PIE is important in the management of the ventilated premature infant. The presence and extent of PIE is directly related to mortality [8]. It also predisposes to the development of pneumothorax [3] which if under tension may itself be fatal. More recently Doppler studies of cerebral blood flow in the newborn have shown an association between pneumothorax and cerebral haemodynamic changes that may precipitate intraventricular haemorrhage [11].

It is known that the location of an endotracheal tube in one main bronchus may cause unilateral PIE [12] with collapse of the contralateral lung. In such circumstances selective intubation of the collapsed lung may be necessary in order to protect the lung with PIE from the adverse effects of high ventilatory pressures [13]. It has recently been suggested that the incidence of PIE may be reduced by paralysis in order to prevent active expiration against the ventilator [14, 15] and the insufflation of artificial



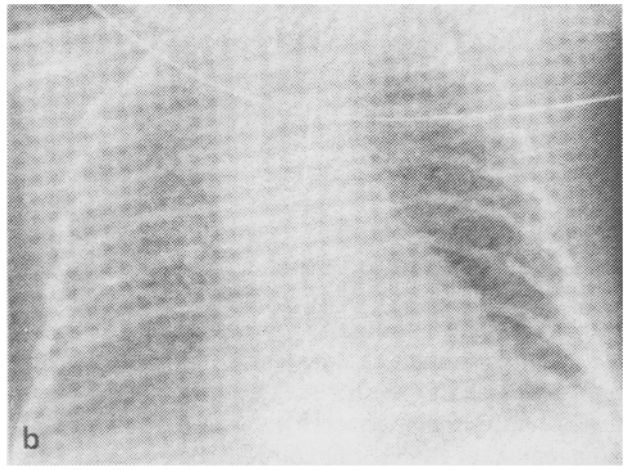


Fig. 5a. Distended perivascular lymphatic ducts (arrowed) into which haemorrhage has occurred. H and E × 36. **b** Peripheral deaeration of the lung is seen more marked on the right

		Pathology		
		1	11	111
Radiology	I	5	1	1
	II	1	6	2
	III	0	0	3

Fig. 6. Two-way frequency chart showing the combinations of radiological and pathological gradings

surfactant [16] are both means by which the incidence of PIE may be reduced in the future. Surgical resection of severe, localised PIE has been undertaken [17], but this is rarely necessary since most cases resolve spontaneously if ventilatory support can be discontinued.

PIE is an inevitable complication of the ventilatory management of these premature babies who cannot be adequately ventilated without high pressures. The earlier radiological recognition of PIE will alert the paediatrician to the potential development of complications and may in some instances encourage altered management and the avoidance of the more severe complications.

Acknowledgements. We thank Dr. J. G. B. Russell and Dr. M. L. Chiswick for their advice and encouragement during this study.

References

1. Laennec RTH (1837) Traité de l'auscultation médiate, 4th edn. JS Chaude, Paris
2. Prosser R (1964) Interstitial emphysema in the newborn. Arch Dis Child 39: 236
3. Campbell RE (1970) Intrapulmonary interstitial emphysema: a complication of hyaline membrane disease. Am J Roentgenol Nucl Med 110: 449
4. Burnard ED, Gratton-Smith P, John E (1976) A radiographic, pathologic and clinical study of interstitial emphysema complicating hyaline membrane disease. In: Stern L, Friis-Hansen B, Kildeberg P (eds) Intensive care of the newborn. MTP Press, Lancaster
5. Kelman SR (1919) Experimental emphysema. Arch Intern Med 24: 332
6. Caldwell EJ, Powell RD, Muliooky JP (1970) Interstitial emphysema: A study of physiologic factors involved in experimental induction of the lesion. Am Rev Respir Dis 102: 516
7. Macklin CC (1939) Transport of air along sheaths of pulmonic blood vessels from alveoli to mediastinum. Clinical implications. Arch Intern Med 64: 913

8. Thibeault DW, Lachman RS, Laul VT, Kwong MS (1973) Pulmonary interstitial emphysema. Am J Dis Child 125: 611
9. Plenat F, Vert P, Didier F (1978) Pulmonary interstitial emphysema. Clin Perinatol 5: 351
10. Nagaishi C (1972) Functional anatomy and histology of the lung. University Park Press, London
11. Hill A, Pelham JM, Volpe JJ (1982) Relationship of pneumothorax to occurrence of IVH in the premature newborn. Paediatrics 69: 144
12. Greenough A, Dixon AK, Roberton NRC (1984) Pulmonary interstitial emphysema. Arch Dis Child 59: 1046
13. Brooks JG, Bustante SA, Koops BL, Hilton S, Cooper D, Wesenberg R, Simmons MA (1977) Selective bronchial intubation for the treatment of severe localised pulmonary interstitial emphysema in new born infants. J Paediatr 91: 648
14. Greenough A, Morley C, Davis J (1983) Interaction of spontaneous respiration with artificial ventilation in preterm babies. J Pediatr 103: 769
15. Greenough A, Morley CJ, Davis JA, Woods (1984) Pancuronium prevents pneumothoraces in ventilated premature babies who actively expire against positive pressure ventilation. Lancet I: 1
16. Greenough A, Roberton NRC (1985) Morbidity and survival in neonates ventilated for the respiratory distress syndrome. Br Med J 290: 597
17. Fletcher BD, Outerbridge EW, Youssef S, Bolonde RP (1974) Pulmonary interstitial emphysema in the newborn infant treated by lobectomy. Paediatrics 54: 808

Received: 7 July 1987; accepted: 28 August 1987

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Literature in pediatric radiology (continued from p. 189)

Malattia di Gaucher tipo I. Bolesani, C. et al. (Div. Ped., Presidio Ospedaliero, I-35013 Cittadella, PD, Italy) **39,** 531 (1987)
Periostosi multifocale ricorrente infantile. Sangermani, R. et al. (Div. Ped., Ospedale San Carlo Borromeo, Via Pio II, 3, I-20153 Milano, Italy) **39,** 545 (1987)

Radiologia Medica (Torino)
Quadri radiografici delle localizzazioni al piede del sarcoma di Ewing. Albisinni, U. et al. (Giunti, A., I Clinica Ortop. Univ., Ist. Ortop. Rizzoli, Via Codivilla 9, I-40136 Bologna BO, Italy) **73,** 501 (1987)
L'ecografia nella displasia dell'anca del neonato e del lattante. Psenner, K. et al. (Ospedale Generale Regionale, Via L. Böhler 5, I-39100 Bolzano BZ, Italy) **73,** 505 (1987)

Radiologia (Madrid)
Visualización de un ganglioneuroma mediante gammagrafía con ^{131}I-MIBG. Tortajada, J. F. et al. (Unidad de Oncologia Ped., Hosp. Infantil "La Fe", Avda de Campanar, 21, E-46009 Valencia, Espania) **29,** 286 (1987)

Rentgenologija i Radiologija (Sofia)
Pulmonary metastases of solid malignant tumors in childhood. Hristozova, I. et al. **26,** 7 (1987)

Indian Journal of Radiology & Imaging (Bombay)
Prune-belly syndrome. Sahoo, Y. et al. (Dept. of Rad., TELCO Hosp., JAM-SHEDPUR-831004 (Bihar) **41,** 37 (1987)
Intra-ventricular tumour in tuberous sclerosis (with CT findings). Madhusudhanan, M. et al. (Med. College, Kottayam (Kerala), India) **41,** 41 (1987)
Branchial fistula. Singh, M. H. et al. (On study leave at Apollo Hosp., Madras (Tamil Nadu) **41,** 53 (1987)
Kleeblattschadel syndrome. Singh, J., Vashisht, S. (All India Inst. of Med. Sciences, Ansari Nagar, New Delhi-110029, India) **41,** 103 (1987)

Acta Paediatrica Japonica (Tokyo)
A case of pelvic osteomyelitis. Matsukura, H. et al. (Dept. of Ped., Faculty of Med., Toyama med. and Pharmaceutical Univ., 2630 Sugitani, Toyama 930-01, Japan) **29,** 277 (1987)
Pyogenic liver abscess due to bacteroides fragilis. Ka, K. et al. (Dept. of Ped., Saitama Med. School, 38 Morohongo, Moroyama-machi, Irumagun, Saitama, 350-04, Japan) **29,** 280 (1987)

Pediatriia (Moskva)
Medical errors in diagnosis of foreign bodies in respiratory tract and esophagus. Lisitsyn, E. D., Chistyakova, V. R. (Head Otorhinolaryng., Ped. Faculty II, Med. Inst. "Piropon", Moskva, USSR) **7,** 65 (1987)

Vestnik Rentgenologii i Radiologii (Moskva)
Childhood roentgenology: problems of development (to the international day in defence of children). Filippkin, M. A. (Head of Pediatr. Radiol., ZOLJ UW, Moskva, USSR) **3,** 5 (1987)
Present-day concepts of radiodiagnosis of acute pneumonias in children. Mirimova, T. D., Zhakova, I. I. (Inst. of Ped., X-Ray-Dept., Acad. of Med. Sci., Moskva, USSR) **3,** 11 (1987)
Chronic nonspecific lower lobular pneumonia and common lung hypoplasia complicated by an inflammatory process in children. Poida, Z. S. (Kathedra of Roentgenol., Inst. of Postgrad. Med., Kiev, USSR) **3,** 16 (1987)
Combined X-ray study in the assessment of chronic nonspecific pulmonary diseases in children during a follow-up. Novikov, V. P. et al. (Kathedra of Roentgenol. and Rad., Med. Inst. Omsk, USSR) **3,** 23 (1987)
Radiodiagnosis of lung mucoviscidosis in children and adults. Kartavova, V. A. et al. (Sci. Inst. of Pulmonol., Leningrad, USSR) **3,** 27 (1987)
X-ray study of the thoracic organs in children with acute lymphoblastic leukemia. Filshtinsky, A. Ya., Efimenko, S. I. (Kathedra of Roentgenol., Ukrain. Inst. of Postgrad. Med., Children's Hosp. No. 16, Charkov, USSR) **3,** 32 (1987)
Radiodiagnosis of hypertrophic cardiomyopathy in children and adolescents. Alexandrova, O. G. et al. (X-ray Dept., Cardiol. Dept., Inst. of Ped., Acad. of Med. Sci., Moskva, USSR) **3,** 38 (1987)
X-ray characteristics of abnormal branching out of the left coronary artery from the pulmonary trunk. Kiseleva, I. P., Abdullaev, F. Z. (Inst. of Cardiol. and Angiol. Surg. "Bakulev", Acad. of Med. Sci., Moskva, USSR) **3,** 44 (1987)
X-ray signs of the left ascending aorta in congenital heart disease. Ivanitsky, A. V., Safonova, N. I. (X-ray Dept., Inst. of Cardiol. and Angiol. Surg. "Bakulev", Acad. of Med. Sci., Moskva, USSR) **3,** 49 (1987)
Diagnostic potentialities of neurosonography in premature infants. Gavryushov, V. V. et al. (Kathedra of Neonatol., ZOLJUB, Moskva, USSR) **3,** 52 (1987)
Computerized tomography in the diagnosis of chronic subdural hematomas in children. Artaryan, A. A. et al. (Head of Ped. Neurosurg., Inst. of Neurosurg. "Burdenko", Acad. of Med. Sci., Moskva, USSR) **3,** 57 (1987)
Radiodiagnosis of chronic pancreatitis in children. Batenkova, Yu. V. et al. (Sci. Inst. of Ped., Minist. of Health RSFSR, Gorki, USSR) **3,** 60 (1987)
Disturbance of growth of the vertebral bodies in children and adolescents with hematogenous osteomyelitis of the vertebral column. Sizov, V. A. (Head of Roentgenol., State Inst. DUW, Kiev, USSR) **3,** 66 (1987)
On the assessment of roentgenologic evidence for the lungs of healthy infants. Bogadelnikov, I. V. et al. (Sci. Inst. of Endoscopy, Head of Ped. Rad., ZOLJUW, Moskva, USSR) **3,** 74 (1987)
Roentgenosemiotics of coarctation of aorta in children. Golonzko, R. R. et al. (Inst. of Cardiol. and Angiol. Surg., Acad. Med. Sci. "Bakulev", Moskva, USSR) **4,** 69 (1987)

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