Unilateral Pulmonary Agenesis

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Hitherto descriptions of some 200 cases of this condition have been published. In the majority of these reports a single case has been presented in detail together with the investigations showing how the diagnosis was made. Some authors have recorded a small series of cases, and in an effort to increase the number there has often tended to be indiscriminate use of the term agenesis. As a result of this considerable confusion has arisen.

In 1912, Schneider classified the condition according to the extent of the defect. In Group 1 he included only those cases with a complete absence of the lung and bronchus. In Group 2 there was no evidence of any lung tissue, but the beginning of a bronchus was noted as a blind pouch or pit. There has been little difficulty in classifying cases into either of these two groups. In Group 3 he described the bronchus as being essentially normal and ending in a fleshy structure.

Many authors have had difficulty in deciding whether a particular case of this kind should be considered as an example of Group 3 agenesis or hypoplasia. The first cases to be described were all diagnosed *post mortem*, when it became apparent that in this condition there was also absence of the pulmonary artery on the affected side. It has been suggested, therefore, that if vessels can be demonstrated giving blood to the fleshy structure that this no longer constitutes agenesis and that such a case must therefore be classified as hypoplasia. However, as will be shown later, this is not strictly true, and there remain some cases that defy attempts at inclusion in Schneider's Group 3 or hypoplasia.

More recently (Boyden, 1955) a more practicable classification has been recommended based on the degree of developmental arrest, viz. *Group 1* complete absence of one or both lungs (agenesis); *Group 2* suppression of all but a rudimentary bronchus (aplasia); *Group 3* abortive growth (hypoplasia). In this terminology there is no need to attempt to distinguish between 'type 3 agenesis' and 'hypoplasia'.

Several authors have compared their cases with those already published (Hurwitz and Stephens, 1937; Smart, 1946; Wexels, 1951; Oyamada, Gasul, and Holinger, 1953; Valle, 1955). Until 1950, out of 55 reported cases the diagnosis during life had been made on only 16 occasions (Ingram, Hudson, and Davis, 1950). Since that time, the percentage of diagnoses during life has risen considerably; it remains true, however, that just under half of the patients with this condition die in the first year of life. In several adults dying from other causes, absence of a lung has been demonstrated at necropsy. The condition is thus compatible with long survival. The over-all incidence of this congenital anomaly has proved impossible to estimate (Delarue, Paillas, Abelanet, and Chomette, 1959).

Here 17 cases are recorded, of which 8 are still living and have been followed from infancy. In this series the characteristics of the condition have been illustrated and the associated ipsilateral abnormalities described. As will be seen from Table I, the incidence of anomalies in the living cases is considerably higher than previously reported. The main findings in the whole group are recorded in Table II, the details of those that died in Table III, and of those that still survived in Table IV.

Clinical Examination

The difficulty of diagnosis depends on the side of the absent lung, the apparent dextrocardia induced by absence of the right lung being a striking clinical finding. When the right lung is absent, the heart is rotated in a clockwise direction and the apex beat is felt in the 3rd or 4th space in the right mid axillary line. Air entry in the underlying left lung is often heard in the right paravertebral and parasternal areas, but is absent in the right axilla, and the right diaphragm is raised. These findings show that with absence of the left lung, the heart sounds are louder than normal over the apex beat.

When examining 5 out of the 9 cases at follow-up, there was obvious flattening of the chest on the affected side with impaired movement on inspiration. It is suggested that the asymmetry of the chest becomes more noticeable in the adult patient

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TABLE I
Distribution of 17 Cases

Cases	Sex	Side of Agenesis	Associated Abnormalities					
			Heart	Gut	Spine	Face	Limb	Kidney
Dead (9)	5 F 4 M	2 L 7 R	5	4	4	2	1	1
Living (8)	4 F 4 M	5 L 3 R	1	0	4	6	2	0

TABLE II
Details of Cases

Case No.	Age and Sex	Side of Agenesis	Symptoms and Signs	X-ray Findings
1	1 dy., F	Rt.	Cyanosed from birth; poor expansion of rt. side of chest; absent air entry on rt.; heart sounds maximal at rt. sternal border	Rib anomalies; multiple defects of vertebral body segmentation
2	5 dy., F	Rt.	Cyanosed at birth; hypotonic lower limbs; breath sounds diminished on rt.; dextrocardia	Rt. hemithorax opaque
3	2 mth., M	Rt.	Cyanosed at birth; feeding difficulty; depressed, poorly moving rt. side of chest; poor air entry; heart displaced to rt.	Rt. hemithorax opaque
4	2 mth., M	Rt.	Difficulty in breathing during feeding, dyspnoea following feeds; air entry absent on rt.; heart displaced to rt.	Partial herniation of lt. lung across midline; ?6 lumbar vertebrae
5	10 wk., M	Rt.	Cyanosed at birth; dyspnoea; convulsions; dextrocardia, loud systolic murmur	Chest x-ray film—(see Fig. 6); 14 pairs of ribs; defective segmentation of sacrum
6	9 mth., M	Rt.	Other abnormalities noted, see Table III	Anomalies of vertebrae, kyphosis in dorsal region; rib anomalies
7	11 mth., F	Lt.	Other abnormalities, see Table III	Associated abnormalities of ribs; disorganization at lt. inferior radio-ulnar joint (Fig. 16)
8	10 yr., F	Rt.	Flattening of lt. chest developed during first 2 yr.; apex beat in rt. mid-axillary line	Lt. lung herniated across midline anteriorly; angiocardio-gram; no rt. pulmonary vessels
9 (Brimblecombe, 1951, case 3)	4 mth., F	Lt.	Cyanosis when feeding; dyspnoea; movements of lt. chest diminished, breath sounds markedly diminished on lt.; heart shifted to lt.	Chest x-ray film published previously (Brimblecombe, 1951)
10	4½ yr., M	Lt.	Dyspnoea of effort; cyanosed at birth; repeated respiratory infections as baby, now well; chest slanting of ribs, flattening of lt. chest; air entry normal on rt., and in lt. parasternal region	Lt. hemithorax opaque, crowding of ribs; rt. lung herniated anteriorly
11	7½ yr., F	Lt.	Haemorrhage from lower bowel aet. 2 dy.; slight cyanosis on crying; recurrent chest infections as infant; increasing scoliosis	Lt. hemithorax opaque (Fig. 5); reduced in size by scoliosis; multiple vertebral and rib abnormalities
12	7½ yr., F	Rt.	Slightly cyanosed after birth; respiratory infections as an infant; well for 5 yr., then pneumonia (7 yr.); dyspnoea of effort; rt. chest—infraclavicular hollow, and slight flattening; rt. trapezius deficient	Dextrocardia; mediastinum shifted to rt.; lt. lung herniated into rt. hemithorax

continued

TABLE II—*continued*

Case No.	Age and Sex	Side of Agenesis	Symptoms and Signs	X-ray Findings
13	12 yr., M	Lt.	Minimal respiratory difficulty in infancy; chest: lt. side flattened; infraclavicular hollow; trapezius deficient, lt. scapular more prominent; air entry in lt. parasternal region	Lt. hemithorax opaque; 13 pairs ribs, 3rd rib rudimentary on lt.
14	17½ yr., M	Rt.	Cyanosed at birth; 3 yr. recurrent respiratory infections; dyspnoea of effort; chest flattened on rt., infraclavicular hollow; trapezius deficient; air entry in rt. parasternal area	Dextrocardia
15	18 yr., M	Rt.	Well until 9 mth., then recurrent pneumonia for several yr.; dyspnoea of effort; chest: flattening of rt. side; scoliosis to rt.; prominent rt. scapular (Fig. 4); air entry in rt. parasternal area	Dextrocardia
16 (Brimblecombe, 1951, Case 4)	19 yr., F	Lt.	Cyanosed at birth; dyspnoea of effort; chest: lt. side flattened, breast higher than on rt. side; lt. scapular more prominent; lt. pectoralis major muscle smaller	Lt. hemithorax opaque; marked deviation of trachea and mediastinum to lt.; rt. cervical rib; T. 4 and 5 present as hemivertebrae; dorsal scoliosis
17 Field, 1946, Case 1)	23 yr., F	Lt.	Occasional vomiting in early life; mentally retarded; chest: slight supraclavicular hollow; air entry in lt. parasternal area; some deficiency of lt. trapezius	Lt. hemithorax opaque; rt. lung herniated across mid-line; spina bifida of T. 1 and 2; dorsal scoliosis

than in the infant, and this may account for the fact that it has not been reported on as many occasions as might be expected when this defect has been discovered in infancy and childhood.

Asymmetry of the chest is well shown in Fig. 1-3. It is less apparent in an adult woman, though in such patients the breast on the affected side may be more conical and less rounded in shape and hang at a slightly higher level than that on the contralateral side.

Investigations

Chest x-ray film. In left-sided agenesis the heart and mediastinum are shifted markedly to that

side. There may or may not be aeration of the apical and paravertebral areas on the affected side, depending on the degree of hypertrophy of the opposite lung.

When the right lung is absent, there is apparent dextrocardia and often herniation of the left lung across the anterior or posterior mediastinum.

On the side of the agenesis it is usual to find the ribs placed closer together and having an imbricated appearance. 13 pairs of ribs are not infrequently encountered and the additional pair may or may not be in the cervical position (Fig. 5 and 6). The apex of the agenetic side is often noted to be filled by the developing thymus gland.

FIG. 1.—Case 12: right agenesis.

FIG. 2.—Case 13: left agenesis.

FIG. 3.—Case 14: right agenesis.

FIG. 4.—Case 15: right agenesis.

Case No.	Side of Agenesis	Lung	Tracheo-bronchial Tree
1	Rt.	Prolongation of lt. lower lobe passed through deficient mediastinum to rt. sided sac apparently lined by pleura (Fig. 11)	After origin of bronchus tracheal rings gave way to oesophageal mucosa; pit opposite lt. main bronchus
2	Rt.	Vestigial rt. lung in paravertebral position, no bronchus, small vascular connexions	Narrowing of trachea just above carina; dimple at site of rt. main bronchus
3	Rt.	Lt. lung unilobular, patchy consolidation	Trachea terminated in lt. bronchus, no rudimentary rt. bronchus
4	Rt.	Absence of rt. lung and pleural cavity (Fig. 12)	Trachea continued as lt. main bronchus, no trace of rt. bronchus
5	Rt.	Necropsy refused; died in congestive heart failure	
6	Rt.	Necropsy refused; died after pulmonary collapse with paradoxical respiration	
7	Lt.	Herniation of rt. lung occupied lt. chest	
8	Rt.	Vestigial rt. lung removed at thoracotomy; lt.-sided compensatory emphysema noted, with herniation of lung across ant. mediastinum	
9	Lt.	No pleural cavity; lt. lung composed of small node applied to tip of bronchus; rt. lung large, bilobed	Trachea divided normally; lt. bronchus 6 mm. long

FIG. 5.—Case 11.

FIG. 6.—Case 5.

III
Examination Findings

Heart	Gut	Other Anomalies
Transposition of great arteries; pulmonary valve atretic, single pulmonary artery; PDA; ASD	Imperforate anus; oesophageal atresia; tracheo—oesophageal fistula; annular pancreas; universal mesentery	Goitre; syndactyly of 2nd and 3rd toes of lt. foot; partial syndactyly of same toes of rt. foot
Large pulmonary artery to lt. lung 2 mm. diameter vessel to rt. lung; PDA; persistent lt. SVC	Duodenal atresia with annular pancreas; universal mesentery; malrotation	
Small pulmonary artery; VSD		Asymmetrical head, low-set ears with malformed pinnae
Single pulmonary artery; PDA	Meckel's diverticulum	Solitary ectopic kidney in pelvis, in mid-line, with single ureter entering bladder at site of rt. uretero-vesical orifice
	Imperforate anus	
		Paraplegic (level T10-12); hamstring and dorsiflexor contractures; kyphoscoliosis in thoracic region (convexity to lt.); asymmetrical head
Blind lt. pulmonary artery; absent lt. pulmonary veins; rt. side of heart hypertrophied		Asymmetrical skull; lt. side of body underdeveloped; shortening of lt. arm; hypotonia; digital positioning of lt. thumb; lt. sternomastoid hypoplastic; lt. ptosis
		Anomalies of spine, including hemivertebra in lower cervical region, posterior spina bifida at T1; anterior spina bifida at T4
Atrio-ventricular septal defect; patent foramen ovale		

Bronchoscopy and bronchography. In the past, bronchoscopy has frequently been performed to establish the diagnosis. Typical findings are recorded in five of the cases in Table IV. The views which may be seen have recently been recorded photographically (Maisano, 1965). A bronchogram con-

firms the type or degree of the malformation which may be particularly difficult to distinguish in Schneider's Groups 2 and 3, when the small atretic bronchus is viewed at endoscopy and found to be full of mucus (Fig. 7 and 8 are typical bronchograms of type 3 agenesis of the left and right lungs, respectively).

FIG. 7.—Case 7.

FIG. 8.—Case 15.

TABLE IV
Other Findings in Survivors

Case No.	Side of Agenesis	Special Investigations	Facial Abnormality	Other Abnormalities
10	Lt.	Bronchoscopy: lt. main bronchus ended in blind stump just below carina; rt. bronchus normal		Partial syndactyly of 2nd and 3rd toes of both feet
11	Lt.		Asymmetry; large accessory auricle of lt. ear	Small hiatus hernia demonstrated radiologically during infancy
12	Rt.	Bronchogram: rt. bronchus ended blindly just beyond carina; lt. bronchus normal	Slight asymmetry, with hypoplasia of rt. mandible	Bilateral inguinal herniae
13	Lt.	Angiocardiography (Fig. 9); absent lt. pulmonary artery; no cardiac lesion	Agenesis of lt. side of face and jaw; underdevelopment of base of skull; microtia, with absence of auditory meatus and middle ear on lt. side (Fig. 13 and 14).	Arm: absent lt. radius; horseshoe-shaped ulna; poorly developed carpus; feeble hand, entire arm weaker than rt., also smaller (Fig. 15 and 17)
14	Rt.		Asymmetrical; underdevelopment of rt. side of mandible and maxilla; rt.-sided deafness	Rt. thumb in digital position, poor thenar musculature; reduced span compared to lt. (Fig. 18)
15	Rt.	Bronchoscopy: rt. main bronchus present, ending blindly; confirmed on bronchography		
16	Lt.	Bronchoscopy: abnormal origin of eparterial bronchus (rt. side); bronchogram: lt. bronchus ends blindly 8 mm. from carina; abnormality on rt. confirmed and additional bronchus noted (Fig. 7 and 8, published previously)	Lt. cheek less prominent than rt.	PDA ligated at 10 yr. of age
17	Lt.	Bronchoscopy: trachea narrow, no lt. main bronchus; rt. bronchus narrow; bronchography; lt. bronchus ended blindly after 5 mm. (Fig. 1, published previously)	Bilateral ptosis	Microcephaly; bilateral talipes equinovarus (now corrected)

FIG. 9.—Case 13.

FIG. 10.

Angiocardiography. This investigation was first performed in a case of hypoplastic left lung by Castellanos and Pereiras in 1942, and since that time it has been used with increasing frequency to demonstrate the absence of a pulmonary arterial supply to the absent lung (Fig. 9 and 10). It has been suggested by Smith and Bech (1958) that when no pulmonary artery can be shown, no pulmonary tissue exists and that the condition is true agenesis; conversely, when a pulmonary blood flow is shown some lung tissue must be present and the condition should be regarded as one of pulmonary hypoplasia. However, it should be remembered that the isolated absence of one of the pulmonary arteries has been reported in patients with two lungs.

Associated Abnormalities

Cardiovascular system. All the common heart abnormalities accompanying unilateral pulmonary agenesis have been recorded, the most common being patent ductus arteriosus; this was present in 3 of our 9 cases which died (Table III). It was the only cardiac abnormality amongst the living patients and in this case the ductus was tied off at the age of 10. The ductus has been tied off in 3 other recorded cases (Nicks, 1957; Jimenez-Martinez, Pérez-Alvarez, Pérez-Treviño, Rubio-Alvarez, and De Rubiens, 1965; Nelson, McMillan, and Bharucha, 1967). It has recently been shown that during the attacks of hypoxia, there may be a bi-directional shunt through the patent ductus arteriosus due to pulmonary hypertension whilst permanent reversal of flow through a patent ductus arteriosus has been recorded in a man with left-sided agenesis (Lukas, Dotter, and Steinberg, 1953; Steinberg and Stein, 1966, Case 3).

Reported abnormalities of the great vessels are recorded in Table V.

Gastro-intestinal abnormalities. It might be expected that tracheo-oesophageal fistula was a

common accompaniment of unilateral pulmonary agenesis, but only 13 cases have been recorded (Table VI). In only one of our series was a tracheo-oesophageal fistula found (Fig. 11). This case was remarkable for the fact that the normal tracheal structure gave way imperceptibly to the lower end of the oesophagus and the left bronchus was given off just above the dividing areas; the only similar reported case seems to be that of Wehr (1934). No other gastro-intestinal abnormality is particularly associated with agenesis. From Table III it will be seen that the accompanying abnormalities in this series were duodenal atresia, annular pancreas, malrotation, Meckel's diverticulum, and imperforate anus. Barium swallow may show deviation of the oesophagus to the agenetic side, particularly when the right lung is absent. Occasionally the diaphragm may be deficient on either the ipsilateral or contralateral side, allowing eventration of the abdominal viscera, but this anomaly is more often seen accompanying hypoplasia.

Spinal abnormalities. The most common associated spinal abnormality is hemivertebra which is not exclusively associated with agenesis and may occur with hypoplasia. The resultant scoliosis may be a severe additional handicap in the child already suffering from recurrent respiratory infection. Such a scoliosis may also result from a rudimentary rib on the affected side (Case 13). Abnormality of the spine or ribs in the cervical or thoracic regions may be attended by a more prominent scapula on the affected side (Fig. 4). It will be seen from Table III, that abnormalities of proper segmentation of the vertebral bodies and failure of ossification are not uncommon, and these are not just limited to the thoracic region (see Fig. 6).

Ipsilateral facial abnormalities. From Table VII, it will be noted that 6 of the 8 living cases had some associated facial or jaw abnormality, always on the ipsilateral side (see Fig. 2 and 3), which indicate

TABLE V
Cases Showing Abnormal Vascular Supply

Author	Side of Agenesis	Vascular Abnormality
Théremin (1884), Case 1	Lt.	Anomalous pulmonary venous drainage to azygos vein
Case 2	Lt.	Anomalous pulmonary venous drainage to azygos vein
Hurwitz and Stephens (1937)	Lt.	Anomalous pulmonary venous drainage of lt. lung rudiment to azygos vein
Castellanos and Pereiras (1942), Case 2	Lt.	Persistent lt. superior vena cava
Thomas and Boyden (1952), Case 3	Rt.	Lt. pulmonary artery posterior to lt. bronchus
Maier and Gould (1953)	Rt.	Aorta anterior to trachea and compressing it; lt. pulmonary artery posterior to trachea
Clark, Scott, and Johnson (1955), Case 1	Rt.	Anomalous pulmonary venous drainage of lt. lung to rt. atrium
Tezok, Balci, Alin, and Gerelioglu (1965)	Lt.	4 pulmonary veins on rt. side
Wheeler, Wolff, and Stevens (1966)	Rt.	Lt. subclavian vein entering lt. atrium, single pulmonary vein entering rt. atrium; 'pseudo-vascular ring' formed by patent ductus arteriosus compressing trachea

FIG. 11.—Case 1.

FIG. 12.—Case 4.

that such anomalies may be more common than has hitherto been recorded (Walker, 1961). Examples so far reported have been included in

Table VII, and it is suggested that Case 13 from our series is a true example of unilateral facial agenesis or hemifacial microsomia (see Fig. 13 and 14)

TABLE VI
Cases Showing Association with Tracheo-oesophageal Fistula

Author	Side of Agenesis	Details of Tracheo-oesophageal Fistula (TOF)	Associated Abnormalities	
			Cardiovascular	Other
Klebs (1874) cited by Meyer (1910)	Lt.	Offshoot from oesophagus to rudimentary lung	PDA	Limb deformities
Paul (1928)	Lt.	Small bronchial communication from hypoplastic lt. lung to lower oesophagus		
Wehr (1934) cited by Bonnholtzer (1938) ..	Lt.	Straight through TOF; atresia of larynx	VSD	Defective lt. diaphragm; spleen and stomach in lt. pleural cavity
Lelong, Vialette, Couder, and Giffard (1950) ..	Lt.	TOF		Hare-lip and cleft palate; absent lt. kidney
Naclerio and Hochberg (1950) Case 1	Rt.	Normal TOF; oesophageal atresia		Horseshoe-shaped kidneys; fused lower lumbar vertebrae
Caussade, Neimann, and Bénichoux (1952) ..	Rt.	Normal TOF; oesophageal atresia	ASD; lt. brachiocephalic vein drained into pulmonary vein	
Macht and Bessinger (1952), cited by Valle (1955)	Lt.	TOF		
Thomas and Boyden (1952) Case 2	Rt.	TOF	Ectopic position of lt. pulmonary artery	
Zhuchkova and Peschanskii (1955)	Rt.	Normal TOF; oesophageal atresia	PDA; single ventricle	
Caramello (1956)	Lt.	Normal TOF		Absent lt. kidney and ureter
Smith and Bech (1958) Case 1	Rt.	Normal TOF; oesophageal atresia		
Warner, McGraw, Peterson, Cleland, and Meyer (1961)	Rt.	Small fistulous track between oesophagus and rudimentary rt. lower lobe		Fusion of several rt. upper ribs; fusion of upper two lt. ribs; vertebral anomalies
Tosi and Ziliotto (1964) ..	Rt.	Normal TOF; oesophageal atresia		

TABLE VII
Cases Showing Associated Facial Abnormalities

Author	Side of Agenesis	Facial Abnormality
Gross (1905)	Lt.	Hypoplasia of lt. side of face; dermoid of lt. eye
Ferguson and Neuhauser (1944), Case 3	Lt.	Deformed lt. external ear
Levi-Valensi, Sudaka, and Eisenbeth (1948)	Rt.	Rt.-sided facial asymmetry with paralysis of 7th nerve
Yount (1948), Twin 1	Rt.	Small deformed rt. ear without a patent canal; skin tab in middle of rt. cheek
Fouquet, Heimann, and Arnoldi (1951)	Lt.	Head tilted to lt. shoulder; facial asymmetry
Bariéry, Choubrac, Vaudour, Turpin, and Manouvrier (1955)	Lt.	Lt.-sided facial hemiatrophy; lt.-sided torticollis
Smith and Bech (1958), Case 1	Rt.	Shapeless rudimentary pinnae
Case 2	Lt.	Bilateral accessory auricles, macrostoma, palate defect
Wilson (1958)	Lt.	Lt.-sided unilateral mandibulo-facial dysostosis
Werner (1960), Case 2	Rt.	Rt.-sided facial paralysis, absence of part of rt. pinna, paralysis of lt. sternomastoid muscle
Jones and Howells (1961), Case 3	Rt.	Bilateral accessory auricles

(Gorlin and Pindborg, 1964). Malocclusion was seen in 3 (Cases 12, 15, and 16).

Ipsilateral limb abnormalities. (See Table VIII.) 2 of the 8 living cases showed marked abnormality of the ipsilateral upper limb. In Case 13 (Fig. 2, 15, and 17) the whole of the left arm was noted to be smaller and less powerful, the left radius was absent, there was some bowing of the ulna, and malformation of the carpus terminating in a smaller and less powerful hand (Riordan, 1955). In Case 14, the arm was again less powerful and smaller in diameter; otherwise the arm and forearm were normally formed, but the right thumb possessed poor thenar musculature and was set further forward in a digital position; consequently, the hand spanned a note less than the full octave spanned by the left hand (Fig. 18). In Case 7, there

was also digital positioning of the thumb accompanied by palmar flexion and rotation of the wrist (Fig. 16). In several of the cases recorded in Table IV, the upper clavicular head of the pectoralis major was either poor or absent on the ipsilateral side, which tended to accentuate the flatness of the chest and gave rise to a definite infraclavicular hollow (Netterville, 1957). In addition, the fibres of the trapezius muscle coming from the occipital and cervical heads were much smaller than on the normal side. Only very rarely is the ipsilateral leg involved, as in Case 7.

Cases occurring in twins. (See Table IX.) In this series, Case 1 was the liveborn of twins; the other twin though macerated showed no abnormalities. Only 5 other cases of this condition occurring in twins have been recorded, and of these only those

FIG. 13.—Case 13.

FIG. 14.—Case 13.

TABLE VIII
Cases Showing Associated Limb Abnormality

Author	Side of Agensis	Limb Abnormality
Gilkey (1928)	Rt.	Absence of rt. radius
Paul (1928)	Lt.	Absence of lt. radius, metacarpal, and basal phalanx of thumb
Altmann (1929), Case 1	Lt.	Absence of lt. first phalanx and metacarpal
Formijne (1938)	Lt.	Lt. arm smaller, lt. thumb rudimentary; (lt. ear smaller, lt. palpebral fissure narrower, lt. breast smaller, lt. leg longer and thicker, thickening of cortex and bowing of lt. femur)
Saxl (1940), Case 1	Rt.	Absent rt. thumb; fusion of fingers of rt. hand
Case 3	Lt.	Duplication of lt. first and second phalanges
Ferguson and Neuhauser (1944), Case 1	Lt.	Absent lt. hand
Smith and Bech (1958), Case 1	Rt.	Absence of rt. radius
Case 3	Lt.	Bilateral absence of radius
Thomas and Boyden (1952), Case 3	Rt.	Supernumerary digit at base of lt. thumb
Borsanyi (1960)	Rt.	Rudimentary rt. thumb; hypoplasia of first metacarpal
Jones and Howells (1961), Case 1	Rt.	Small rt. thumb attached to hand by tag of skin
Henchman and Macarthur (1964)	Rt.	Abnormal rt. thumb attached by thread
Ravetto and Vaccino (1966), Case 1	Rt.	Absent rt. radius, first metacarpal and first digit

FIG. 15.—Case 13.

FIG. 16.—Case 7.

TABLE IX
Cases Occurring in Twins

Author	Side of Agenesis	Details of Twin
Finkelstein (1912)	Rt.	Twin 1: female; rudimentary rt. lung, identical twins
Yount (1948)	Lt.	Twin 2: female; rudimentary lt. lung
	Rt.	Twin 1: male; small deformed rt. ear without patent canal; skin tab in middle of rt. cheek
Thomas and Boyden (1952), Case 2 ..	Rt.	Twin 2: male; short webbed neck; identical twins
	Rt.	Twin 1: female; tracheo-oesophageal fistula, lt. eparterial bronchus, ectopic position of lt. pulmonary artery
Maier and Gould (1953)	Rt.	Twin 2: ? normal
		Twin 1: male; aorta anterior to trachea; lt. pulmonary artery posterior to trachea
Breton and Dubois (1954)	Bilateral	Twin 2: ? macerated
		Twin 1: female; normal; univitelline twins
		Twin 2: female; monster; amelia of arms, partial hypoplasia of lt. leg, absence of neck, mouth, nose; absence of oesophagus etc.
Case 1 of this series (Booth and Berry) ..	Rt.	Twin 1: female; stillborn with advanced maceration; widely patent ductus arteriosus; otherwise normal
		Twin 2: female; placenta: single chorionic sac enclosing 2 amniotic sacs

? = Sex unknown

recorded by Finkelstein (1912) and Yount (1948) have shown the absence of a lung in both twins. In the twins recorded by Yount, the right lung was absent in both babies. In the twins recorded by Finkelstein the absent lung was on the right side in the first twin and on the left in the second. The disparity of the abnormality between twins is inexplicable.

Other abnormalities. Other abnormalities have been recorded, notably of the urogenital system. A small number of cases have been recorded with an absent kidney, with associated abnormalities of the ureter and of its entry into the bladder. No particular pattern is obviously associated with unilateral pulmonary agenesis, except that when a kidney is absent it is almost invariably absent on the ipsilateral side. Abnormalities of the

urogenital system do not seem to predispose to a poorer prognosis. Other associated abnormalities that have been recorded with this condition are, harelip, cleft palate, dislocated hips, perforated nasal septum, hydrocephalus, absent ipsilateral ovary, unicornuate uterus, and double uterus and vagina.

Pathogenesis

Embryology. The tracheo-bronchial groove appears in the fourth week of foetal life as a median ventral diverticulum of the fore-gut. The groove deepens and eventually becomes a tube. A longitudinal groove appears in each lateral wall of this tube and the ridges thus formed in the lumen fuse, separating the oesophagus and trachea. Before this separation has occurred the lung buds develop from the caudal end of its 'tracheal' aspect.

FIG. 17.—Case 13.

FIG. 18.—Case 14.

TABLE X
Lung Function Tests (volumes expressed in litres)

Case No.	Age (yr.)	Height (m.)	Weight (kg.)	Expected				Actual		
				FEV ₁ (Ht.)	FVC (Ht.)	FEV ₁ (age)	FVC (age)	FEV ₁	FVC	% Ratio
10*	4½	0.97	14.5	—	—	—	—	0.4	0.4	100
12	7½	1.25	18.5	1.6	1.8	1.5	1.7	0.9	1.3	69
13	12	1.45	37.5	2.2	2.5	2.4	2.8	1.5	1.7	88
14	17½	1.73	52.5	4.0	4.8	3.4	3.8	2.1	2.7	77
15	18	1.84	66.0	4.5	5.2	4.5	5.0	2.3	3.2	72
16	19	1.62	60.0	3.3	3.7	3.6	4.0	1.3	1.7	76
17	23	1.55	54.5	2.8	3.2	3.6	4.0	1.4†	—	—
18*	6½	1.05	17.5	—	—	—	—	0.7	0.8	82

* No normal values available below age of 7.

† Value unreliable due to patient's mental state; FVC could not be recorded.

The fusion of the ridges extends cranially, but at the cephalic end a communication with the pharynx remains (Broman, 1923). The association of tracheo-oesophageal fistula with agenesis of the lung is thus readily explained.

At the 5 mm. stage, a pair of branchial arteries (the 6th) appear and supply the lung buds. Necrosis of an established lung bud may be considered as a possible mode of causation of this defect; if so, it presumably occurs at about this time. It is harder to explain the associated somatic and renal anomalies, but presumably an adverse factor is acting on embryogenesis at the 3-5 mm. stage.

Development of lung. The existing lung may show infinite variety in its state of development, ranging from being unilobar to having a greater number of lobes than normal. The bronchus may vary considerably in its point of entry, and under these conditions a left eparterial bronchus, bronchi arising above the carina, and also both main bronchi entering the same lung, have all been recorded. After birth, the alveolar volume increases until adult life. During the first 8 years this is due to continued alveolar development, but after that age it occurs as a result of increasing volume of existing alveoli. During the period of growth, there is normally a linear relation between the surface area of the alveoli and the body surface area.

Lung function. The forced expiratory volume and forced vital capacity were measured in 7 out of the 8 cases at follow-up and the results shown in Table X. This confirms that there is a significant reduction in both of these measurements, but that in each case the ratio of the two remains within normal limits (Rosenberg, 1962), suggesting that no abnormality, other than reduction of a total lung volume, has occurred. All the 8 cases showed marked dyspnoea after exercise sustained for approximately half an hour, but no dyspnoea under

ordinary circumstances, suggesting that the rate of accumulation of oxygen debt was raised.

There was no evidence of secondary polycythaemia in any case.

Prognosis

The side of the agenesis affects prognosis. In our series in 7 of the 9 deaths, the right lung was absent; in 6 of the 8 living patients, the left lung was absent. The sexes were almost equally represented. These figures confirm the findings of previous authors; that is, the condition has a poorer prognosis when the right lung is absent (Schaffer and Rider, 1957), apparently due to the associated anomalies. It can be seen from Table III, that an accompanying heart abnormality is more commonly associated with right-sided agenesis.

Out of the 9 cases in Table III, only 1 lived longer than a year; of the remainder, 2 lived less than a week, and 3 lived for 2½ months. Furthermore, of the 9 deaths, 5 had an associated cardiac abnormality, whereas in the living series there was only one such case—apparently when there is an associated cardiac abnormality the prognosis is considerably more grave.

Associated abnormalities of other systems of the body do not seem to indicate a similarly poor prognosis, with the exception of malformations of the spinal column (Marioni, 1962).

It is immediately obvious that any infection of the one lung may have its serious consequences. When type 3 agenesis or hypoplasia is present the lung tissue may become the site of recurrent infection and consequently its removal becomes essential. Recurrent infection or an associated cardiac abnormality may cause finger clubbing, but this is never present as a result of uncomplicated agenesis.

Summary

Seventeen cases of unilateral pulmonary agenesis are described and illustrated. The abnormalities

that they show have been compared with those recorded for other patients in the literature to demonstrate both the characteristic features of the condition and the associated generalized developmental defects. An increased percentage of ipsilateral anomalies is recorded. Lung function tests have been carried out on 7 of the 8 living patients, and confirm that in agenesis of the lung, the growth of the existing lung provides adequate pulmonary function, but that a reduction in vital capacity and exercise tolerance can be demonstrated.

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(We regret that a full follow-up was not possible on Case 11.)

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Addendum

Since this paper was written a further patient has been seen, whose details have been included as Case 18 in Table X; he has no ipsilateral associated abnormalities.