Papers and Originals

Surgical Treatment of Emphysema

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Patients breathless from chronic lung disease present a serious problem in morbidity and mortality in Britain, the U.S.A., and other countries with a temperate climate (Fletcher and Tinker, 1961 ; Bower, 1961). For their successful treatment it is essential to determine how much obstruction there is to the air-flow from their lungs and to try to find the cause of this obstruction, whether it be from bronchitis, asthma, or emphysema, or from some combination of these three commonest causes (Fletcher, Hugh-Jones, McNicol, and Pride, 1963).

Though medical treatment can be effective in patients with labile air-flow obstruction from bronchitis and asthma, many patients are seen who are breathless, with "fixed" air-flow obstruction, associated with emphysema, which is unresponsive to bronchodilator drugs and is either found to remain after some improvement with medical treatment or to be the main lesion itself. Surgical resection of bullae in such patients occasionally helps ; but the reasons for improvement in lung function, when it occurs, have not been clear nor have the results been predictable, though surgery in emphysema has long been practised (Gaensler, 1962).

On theoretical grounds surgery could improve such patients in two ways. First, if bullae are removed and the remaining lung expands to fill their place then the relaxation pressure in expiration of this expanded lung will be greater and there will be less tendency for airways to collapse and air-flow obstruction will be relieved (Campbell, 1958 ; Hugh-Jones, 1963). Secondly, if bullae happen to be ventilated they act as dead-space and their removal will then reduce the total ventilation required for a given gas exchange.

We have developed methods for measuring the regional distribution of gas and blood in the lungs (West, 1963 ; Dollery and Hugh-Jones, 1963) which can be used to find regions of the lung that are poorly perfused with blood, whether bullous or not, and which could therefore potentially be resected or "cobbled." Thus, a study was begun to test the validity of the theoretical arguments about surgery and to observe carefully the results of operation in patients with radiological evidence of emphysema who were extremely breathless from air-flow obstruction caused by expiratory airway narrowing and who we thought could be helped in no other way but by surgery.

The methods of regional lung-function study have been developed over years, so that the study could not be planned as one would have wished. Though it is not a complete study and the patients form a highly selected group the results seem to be of enough interest to warrant a record of our experiences at this stage, since some patients have shown such definite subjective and functional improvement.

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Patients Studied

In all, 52 patients were studied, the ages of whom ranged from 19 to 62 years (mean 49 years) ; there were 46 males and six females. Patients were selected mainly because they showed radiological evidence of a localized transradiancy with paucity and narrowing of the peripheral pulmonary vascular markings. In addition to the localized radiological changes many of these patients had generalized hypertranslucency and vascular attenuation. The distribution of the radiological lesions is shown in Fig. 1. Thirteen patients had bilateral apical translucencies, and nine of them had evidence of generalized emphysema. Fifteen had bilateral basal lesions, 13 of them showing evidence of generalized disease. Fifteen had multiple focal lesions with apparently normal intervening lung. Two had unilateral transradiancy of the whole of one lung. Of six patients with a well-defined local transradiancy, three had simple cysts and in three the lesion occupied most of the right middle lobe. In one patient there was widespread transradiancy with no definite localization.

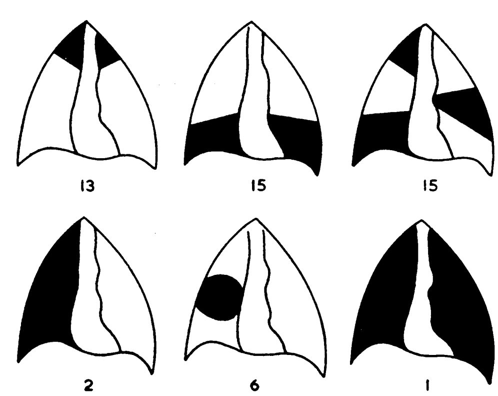

FIG. 1.—Diagram to show the distribution of the transradiancy in the lungs in the 52 patients studied.

Methods

The evolution of the series was such that not all examinations or tests were done on everyone. In the recent part of the series complete studies have been made both before and at least three months after operation, so far as was possible.

Clinical assessment included special attention to a history of bronchitis, sputum volume, wheeze, degree of dyspnoea, and smoking habits following the Medical Research Council (1960) questionary. A history or signs of right heart failure were particularly sought. Laboratory examinations included haemoglobin and packed-cell-volume estimations. Electrocardiograms were graded according to the severity of right ventricular hypertrophy by the criteria of Goodwin and Abdin (1959). Radiological investigation included postero-anterior and lateral chest films, together with whole-lung tomographs. Bronchography was performed in selected cases where bronchiectasis or peripheral bronchial obstruction was suspected.

Lung-function tests were divided into two categories.

1. Overall Assessment

(*a*) *Ventilatory Tests*.—The slow vital capacity (V.C.) and forced expiratory volume in one second (F.E.V.$_1$) were measured from the tracing obtained on a low-resistance spirometer (Bernstein, D'Silva, and Mendel, 1952) with a drum speed of 1.95 cm. per second. Both measurements were repeated after the inhalation of 2% isoprenaline aerosol in air for one and a half minutes. The F.E.V.$_1$ was also expressed as a percentage of the vital capacity (F.E.V.$_1$/% V.C.). Careful examination of the tracings was made for evidence of tracheobronchial collapse (Gandevia, 1963). Normal values for V.C. and F.E.V.$_1$ were predicted from the regression formulae of Kory, Callahan, Boren, and Syner (1961) for males and of Kory, Smith, and Callahan (1966) for females.

(*b*) Total lung capacity (T.L.C.) and subdivisions were measured by the closed-circuit helium dilution method (Gilson and Hugh-Jones, 1949). Normal values for residual volume (R.V.) as a percentage of total lung capacity (R.V./T.L.C. %) were predicted from the formulae of Goldman and Becklake (1959).

(*c*) Carbon monoxide diffusing capacity (DLCO) was measured by the single-breath method of Ogilvie, Forster, Blakemore, and Morton (1957). The breathholding time was calculated according to the suggestions made by Jones and Meade (1960). Normal values were predicted from the regression formulae of Hamer (1962) for males and of Newman (1962) for females.

(*d*) *Exercise Test*.—Respiratory frequency, pulse rate, and minute-ventilation were measured at rest and on graded levels of exercise in the sitting position on a bicycle ergometer. Expired air was collected into Douglas bags over five minutes at rest and during the fifth minute of exercise. Gas volumes were recorded by emptying the Douglas bags through a dry-gas meter. Mixed expired air samples were analysed for carbon dioxide and oxygen content in the Lloyd-Haldane apparatus (Lloyd, 1958). Arterial blood was sampled from an indwelling catheter in the brachial artery at rest and during the fifth minute at each exercise level. Measurements of arterial blood carbon dioxide tension (Pa_{CO_2}), oxygen tension (Pa_{O_2}), and *p*H were made by means of Radiometer carbon dioxide, oxygen, and *p*H electrodes respectively. Oxygen saturation was calculated from Severinghaus's (1958) line graphs. Calculations of physiological dead-space (VD) as a fraction of the tidal volume (VD/VT) were made by use of the Bohr equation. Alveolar oxygen tension (PA_{O_2}) was calculated from the alveolar air equation (Fenn, Rahn, and Otis, 1946). The difference between alveolar and arterial oxygen tensions (PA_{O_2}–Pa_{O_2}) was recorded. Maximum normal values used for $\dot{V}E$, VD/VT, and PA_{O_2}–Pa_{O_2} on exercise were determined by Jones (1964). All gas volumes were expressed at body temperature and standard pressure saturated with water vapour.

2. Regional Function

(*a*) *Xenon-133* (^{133}Xe).—Scans were made of the lungs of patients in the sitting position with vertically moving scintillation counters after the catheter injection of ^{133}Xe in saline into the superior vena cava, again after a tidal breath of a ^{133}Xe-in-air mixture and after rebreathing this mixture for two minutes. The method has been described in detail by Dollery and Gilliam (1963).

(*b*) Lobar gas flows were measured at bronchoscopy under local anaesthesia by means of an argon flow-meter, as described by Hugh-Jones and West (1960). During this procedure careful examination of the bronchial tree was made for segmental bronchial obstructions and evidence of tracheobronchial collapse during expiration. Localized expiratory airways

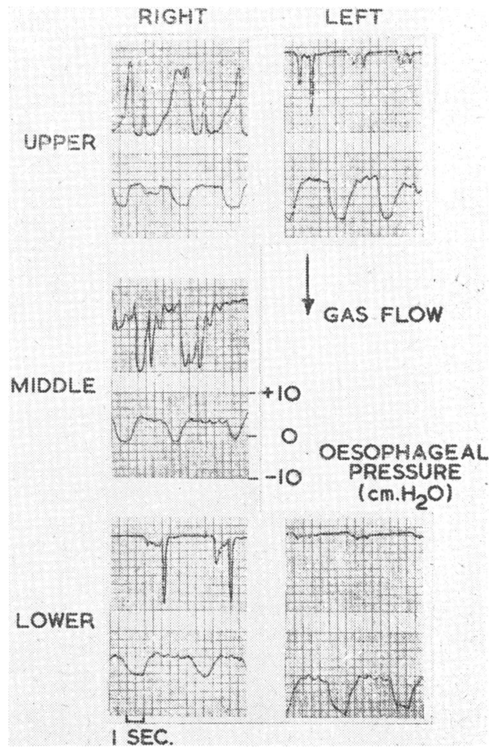

FIG. 2.—An example of a mass-spectrometer record from the bronchial flow-meter in which lobar gas-flow is related to intra-oesophageal pressure. In this patient (Case 10) it can be seen that most of the tidal volume goes to the right upper and middle lobes, little goes to the right lower and left upper, and a negligible amount to the left lower lobe—as judged by the area of the flow tracings. The right lower lobe gives a good example of local expiratory airway narrowing, in which there is an initial rapid peak of gas-flow in expiration followed by a sharp decline, in contrast to the rounded expiratory curve of the right upper lobe. (For further details of the interpretation of such records see West and Hugh-Jones, 1961.)

collapse, confined to lobar or segmental bronchi, could be detected from the mass spectrometer tracings from the argon flow-meter (Fig. 2).

Results

The results in the 52 patients studied are summarized in Table I. Of the 11 patients who were not recommended for surgery nine were rejected owing to the presence of gross bronchitis. Two were not considered suitable because of the generalized nature of the lesion and inability to localize a suitable area for resection. Four patients were deferred for reassessment at a later date after medical treatment of their bronchitis. Of 37 patients recommended for surgery 24 have been operated on, nine await operation, and four declined the recommendation for surgery.

TABLE I.—*Results in 52 Patients Studied*

Not recommended for surgery		11
Deferred		4
Recommended for surgery		37
A. Operated		24
Improved	9	
Not improved	5	
Died	5	
Result unknown	5	
B. Awaiting surgery		9
C. Recommendation not accepted		4

Patients Submitted to Surgery

Clinical Features

Table II shows the clinical features in 19 of the 24 patients submitted to surgery in whom post-operative data were available. Nine patients showed improvement in lung function, five showed a reduction or little change, and five died in the post-operative period. Only three of these patients had no clinical evidence of chronic bronchitis, and in the whole series only nine out of 52. The electrocardiogram was abnormal in 10 out of 15 of these patients, and in three of the five who died post-operatively right ventricular hypertrophy was present. A variety of surgical procedures were performed, being equally divided between plication, resection, and lobectomy, with one hilar denervation where bullae were not found on exposure of the chest (Case 16). A notable finding was that of the six patients who had surgery to the lower lobes five showed improvement in lung function.

Patients Improved by Surgery

Table III presents the overall lung-function tests in nine patients who showed improvement in either V.C. or F.E.V.$_1$. This did not necessarily correlate with subjective improvement as seen in two patients (Cases 1 and 3) or with other functional parameters (Cases 1 and 7). One patient (Case 6) showed a marked reduction in physiological dead-space with dramatic subjective improvement following bilateral lower lobectomies. In two patients (Cases 7 and 8) with subjective improvement, where exercise studies were complete, no change in $\dot{V}_E$ was found, though some improvement in V.C. and F.E.V.$_1$ occurred.

Patients Unimproved by Surgery

Table IV shows the overall lung-function results in five patients who were not improved by operation. None of these

Table II.—*Clinical Findings and Results in 19 Patients Submitted to Surgery*

Case No.	Sex	Age	Chronic Bronchitis	Electrocardiogram	Radiological Localization by Zones of Bullae or Increased Transradiancy	Operation	Functional Result
1	F	50	0	P pulmonale	L.L.Z. > R.L.Z.	Resection basal segments L.L.L.	Improved
2	M	46	+	Normal	R.M.Z.	Plication bulla R.M.L.	Improved
3	M	40	+	—	L.U.Z.	Excision bullae R.U.L.	Improved
4	M	53	+	P pulmonale R.V.H. Gr. I	R.L.Z. L.L.Z.	Excision bullae R.L.L. Ligation R.L.L. bronchus. R. hilar denervation	Improved
5	M	55	+	Atrial fibrillation P pulmonale R.V.H. Gr. I	R.L.Z. L.L.Z.	Plication bullae L.L.L.	Improved
6	F	48	+	P pulmonale	R.L.Z. L.L.Z.	Bilateral lower lobectomies	Improved
7	M	44	+	Normal	R.U.Z. L.U.Z.	Plication bullae R.U.L. R.M.L.	Improved
8	M	50	+	Normal	R.L.Z. > L.L.Z.	Excision cardiac segment. Plication bulla R.L.L.	Improved
9	M	62	+	P pulmonale	L.L.Z.	Plication bulla L.L.L.	Improved
10	M	37	+	P pulmonale R.V.H. Gr. III	Periphery whole of left lung	Plication bulla in lingula	Not improved
11	M	45	+	—	R.U.Z.	R.U. lobectomy	Not improved
12	M	40	+	P pulmonale	R.U.Z. L.U.Z.	1. Plication bullae R.U.L. 2. Plication bullae L.U.L.	Not improved
13	M	62	0	Normal	R.U.Z. > L.U.Z.	R.U. lobectomy	Not improved
14	M	50	+	Normal	Generalized. Maximum L.L.Z.	Excision basal segments L.L.L.	Not improved
15	M	58	+	R.V.H. Gr. I	L.U.Z. Bilateral parahilar bullae	Plication bullae L.U.L. R.L.L. bronchus ligated	Died
16	M	37	+	R.V.H. Gr. II	R.U.Z. L.U.Z.	No bullae found. R. hilar denervation	Died
17	M	57	+	—	R.U.Z. L.U.Z.	Plication bullae L.U.L. R.U. lobectomy	Died
18	M	48	0	R.V.H. L.V.H. (systemic hypertension)	Whole left lung U.Z. > L.Z.	L.U. lobectomy	Died
19	M	41	+	—	R.U.Z. L.U.Z.	R.U. lobectomy	Died

Table III.—*Overall Lung Function in Patients Improved by Surgery*

Case No.	V.C.* (l.)	F.E.V.$_1$* (l.)	F.E.V.$_1$† / V.C. %	R.V. / T.L.C. (%)‡	D_{LCO} (ml./min./mm. Hg)*	Work Load (Kg.M/min.)	$\dot{V}_E$‡ (l./min.)	Exercise Test V_D/V_T‡	Pa_{O_2} (mm. Hg)	Pa_{O_2}–$P_{A_{O_2}}$§ (mm. Hg)	Sa_{O_2} (%)	Pa_{CO_2} (mm. Hg)	Comment
1 (a)	1·20 (36)	0·57 (21)	48	—	6·7 (28)	(a) —	—	—	—	—	—	—	Improvement in V.C. but fall in F.E.V.$_1$ and D_{LCO}. No subjective improvement
1 (b)	2·47	0·53	22	52 (34)	4·2	(b) Rest 100	8·6 20·0 (21·0)	0·28 (0·40) 0·42 (0·30)	78 66	28 34	94 87	42 49	
2 (a)	1·73 (40)	0·80 (23)	46										Significant subjective and functional improvement
2 (b)	2·21	1·10	49										
3 (a)	4·40 (90)	2·30 (66)	52	—	—	(a) —	—	—	—	—	—	—	Despite increase in F.E.V.$_1$ no subjective improvement
3 (b)	4·77	3·03	64	40 (39)	16·7 (63)	(b) Rest 500	16·0 42·0 (34·0)	0·37 (0·40) 0·27 (0·24)	113 95	17 24	98 87	26 34	
4 (a)	2·06 (49)	0·78 (24)	35	57 (31)	16·3 (68)								Minimal change in V.C. Subjective improvement
4 (b)	2·20	0·65	35	—	—								
5 (a)	2·25 (57)	0·60 (19)	26										Subjective and functional improvement
5 (b)	2·60	0·80	30										
6 (a)	2·20 (66)	0·55 (20)	25	71 (36)	4·4 (20)	(a) Rest	9·3	0·68 (0·40)	46	30	81	56	Considerable fall in physiological dead-space. Dramatic subjective improvement
6 (b)	2·38	0·99	43	—	5·2	(b) Rest 100	7·4 20·5 (22·0)	0·30 0·33 (0·30)	75 63	34 41	93 90	37 42	
7 (a)	2·82 (72)	0·65 (20)	23	46 (32)	7·3 (31)	(a) Rest 200	10·0 34·9 (31·0)	0·25 (0·40) 0·45 (0·25)	81 60	19 30	95 86	47 56	Increase in V.C. and F.E.V.$_1$. Improved Pa_{O_2} and lower Pa_{CO_2}, particularly on exercise
7 (b)	3·24	1·08	33	52	7·4	(b) Rest 200	12·4 32·8 (30·0)	0·44 0·35 (0·26)	83 74	30 40	94 91	38 39	
8 (a)	2·98 (76)	1·12 (35)	38	36 (39)	10·1 (44)	(a) Rest 400	8·7 31·0 (32·0)	0·31 (0·40) 0·34 (0·24)	69 73	38 27	92 91	40 48	Subjective improvement associated with improved D_{LCO} and blood gas status. Little change in ventilatory function
8 (b)	3·03	1·19	39	45	15·0	(b) Rest 400	6·7 29·5 (30·0)	0·37 0·32 (0·26)	86 80	24 21	96 94	37 38	
9 (a)	2·41 (63)	0·60 (20)	25										Subjective and functional improvement
9 (b)	2·64	0·86	31										

* Percentage of predicted values in parentheses. † Normal > 70%. ‡ Predicted values in parentheses. § Normal values < 20 mm. Hg.
(a) Pre-operative values. (b) Post-operative values.

claimed subjective improvement at the time of post-operative reassessment. The pre-operative studies of five patients who died in the post-operative period are included. A reduction or little change in the V.C. or F.E.V.$_1$ was the most consistent finding.

One patient (Case 12), a man aged 40, who suddenly became grossly breathless on exertion over about two years and who had negligible bronchitis, was of special interest in that he was unusual in having ventilation of the bullous area. Patients usually have very little ventilation and practically no blood-flow in bullae (Dollery and Hugh-Jones, 1963). We were confident that he would be improved by surgery, both because of relief of expiratory air-flow obstruction and because of reduction of dead-space. Indeed, he did show substantial improvement in ventilatory capacity after a first-stage right upper lobe plication, but regressed to the pre-operative state after a second-stage plication of the left upper lobe, associated with the appearance of transradiancy with diminished vascular markings, and bullae at the right base of his lungs (Fig. 3 A and B). It is likely that such patients with upper-zone transradiancy rapidly appearing in youth are examples of the "vanishing

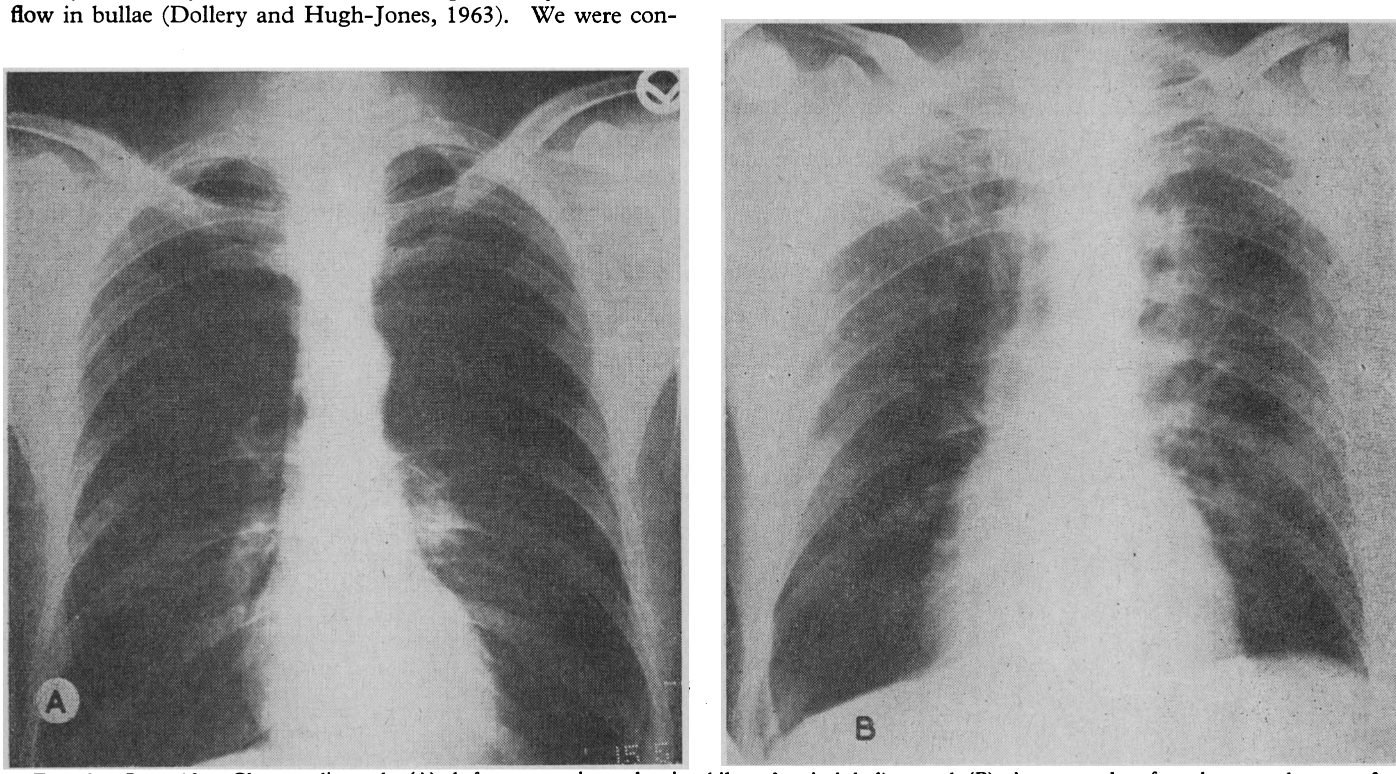

FIG. 3.—Case 12. Chest radiograph (A) before operation, showing bilateral apical bullae, and (B) three months after the second stage of resection of the bullae, showing new bulla at right base.

TABLE IV.—*Overall Lung Function in Patients not Improved by Surgery*

Case No.		V.C.* (l.)	F.E.V.$_1$* (l.)	F.E.V.$_1$/V.C. (%)†	R.V./T.L.C. (%)‡	DLCO (ml./min./mm. Hg)*	Work Load (Kg.M./min.)	$\dot{V}$E‡ (l./min.)	Exercise Test VD/VT‡	PaO$_2$ (mm. Hg)	PaO$_2$–PAO$_2$§ (mm. Hg)	SaO$_2$ (%)	PaCO$_2$ (mm. Hg)	Comment
10	(a)	2·10 (48)	0·60 (16)	29			(a) Rest 50	9·2 15·9 (18·0)	0·47 (0·40) 0·62 (0·32)	— —	— —	82¶ 84¶	48 54	Reduction in F.E.V.$_1$ and deterioration in blood gas tension. No subjective improvement
	(b)	2·00	0·40	20			(b) Rest 50	10·3 13·8 (16·0)	0·62 0·50 (0·36)	40 29	46 43	80 61	58 69	
11	(a)	3·17 (71)	1·34 (37)	42		8·6 (32)								No subjective or functional improvement
	(b)	2·54	1·50	32		—								
12	(a)	2·92 (57)	1·32 (33)	45		—	(a) Rest 200	9·5 18·7 (22·0)	0·47 (0·40) 0·37 (0·29)	70 70	32 39	91 91	42 40	Improvement in V.C. and F.E.V.$_1$ after 1st operation but deterioration to original stage after 2nd procedure. No subjective improvement
	(b)	3·52	1·43	41		—	(b) —	—	—	—	—	—	—	
	(c)	2·93	1·09	37		9·6 (30)	(c) Rest 200	9·6 18·8 (22·0)	0·44 0·40 (0·29)	68 62	33 40	92 87	39 44	
13	(a)	3·45 (97)	1·59 (54)	46		—	(a) —	—	—	—	—	—	—	No subjective or functional improvement
	(b)	3·40	1·50	41	35 (39)	5·9 (16)	(b) Rest 300	11·3 49·2 (32·0)	0·61 (0·40) 0·59 (0·25)	58 57	43 79	88 79	38 44	
14	(a)	4·50 (62)	0·63 (19)	25										Patient died in respiratory failure before re-study one year after operation
15	(a)	2·50 (54)	0·60 (17)	24			(a) Rest Exercise‖	13·2 —	0·52 (0·40) —	62 54	33 —	91 87	60 61	High pre-operative PaCO$_2$. Post-operative death with bronchopneumonia and respiratory failure
16	(a)	1·43 (31)	0·47 (12)	33	76 (29)								49	Very low F.E.V.$_1$. Post-operative death from respiratory failure secondary to bronchopneumonia and pneumothorax
17	(a)	2·20 (38)	0·49 (16)	22			(a) Rest 80	8·0 15·0 (22·0)	0·33 (0·40) 0·30 (0·30)	74 62	32 32	93 89	43 47	Satisfactory operation. Death from aspirated vomitus
18	(a)	1·20 (29)	0·45 (13)	37									52	High pre-operative PaCO$_2$ and low F.E.V.$_1$. Post-operative death from respiratory failure secondary to bronchopneumonia
19	(a)	2·63 (58)	0·70 (19)	23										Post-operative death from respiratory failure secondary to bronchopneumonia

* Percentage of predicted values in parentheses. † Normal values > 70%. ‡ Predicted values in parentheses. § Normal < 20 mm. Hg. ‖ Work load not measured.
¶ Determined by Van Slyke manometric analysis.
(a) Pre-operative values. (b) and (c) Post-operative values.

lung" syndrome of primary pan-acinar emphysema and that surgery has little place in the rapid and relentless progression of their disease.

Post-operative Deaths

The findings in the patients who died within two weeks of operation are also given in Table IV. Four patients (Cases 15, 16, 17, and 19) died of respiratory failure secondary to bronchopneumonia, death in one (Case 16) being complicated by a tension pneumothorax. One patient (Case 17), although progressing satisfactorily, unfortunately died of aspirated vomitus. All the post-operative deaths occurred early in the series in patients with low F.E.V.$_1$, and in two the Pa_{CO_2} was high prior to operation. In three evidence of right ventricular hypertrophy was present on the electrocardiogram.

All these patients were a very poor operative risk, but all were so desperately breathless that life was intolerable and they accepted surgery, knowing the risk.

Regional Function

Table V shows the results of lobar-flow measurements and ^{133}Xe scanning in five selected patients. The close agreement between the ^{133}Xe scan and the bronchial-flow results is shown in three patients (Cases 1, 2, and 7). A typical example of the redistribution of ventilation and blood-flow in both lungs following plication of a right upper and middle lobe bullae is shown in Fig. 4. Change in overall lung function after surgery did not necessarily correlate with the changes in ventilation and perfusion, as shown by the ^{133}Xe scans. In one patient (Case 8) who showed general functional improvement no significant change in ventilation or perfusion could be detected after the resection of a large bulla from the right lower lobe (Fig. 5). A second patient (Case 13), showing redistribution of ventilation and perfusion where this was previously absent, had no subjective or overall functional improvement. In general there was good agreement between the radiological appearances, lobar-flow measurements, and the ^{133}Xe scans. Of the last 18 patients studied under standard conditions agreement between all three methods was satisfactory in 10, between ^{133}Xe scan and radiological appearance in five, in two bronchial-flow measurements were supported by the radiological findings, the ^{133}Xe giving results which were not easy to interpret. With one subject all three methods showed disagreement.

Discussion

That some patients show definite subjective and functional improvement after resection or plication of emphysematous lung is clear. The most predictable improvement has been in the simple ventilatory tests. The significance of changes in other parameters, such as physiological dead-space, alveolar-arterial oxygen tension differences, and ventilation-perfusion inequalities, has not been clear from the data we have at present. But isolated cases have shown subjective improvement coincid-

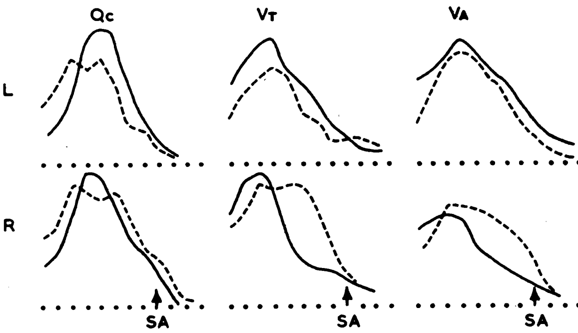

Fig. 4.—Case 7. Xenon scan of the lung showing count rate representing distribution of blood (Qc), single tidal volume (Vt), and rebreathing volume (Va). Pre-operative: continuous line. Post-operative: broken line. Scans, read from left to right, represent distribution from base to apex of lungs, with SA position of the sternal angle. It can be seen that there is ventilation in the right upper zone and the Vt and Va scans where it was previously deficient following plication of a bulla in the right upper and middle lobes and corresponding redistribution of gas and blood elsewhere.

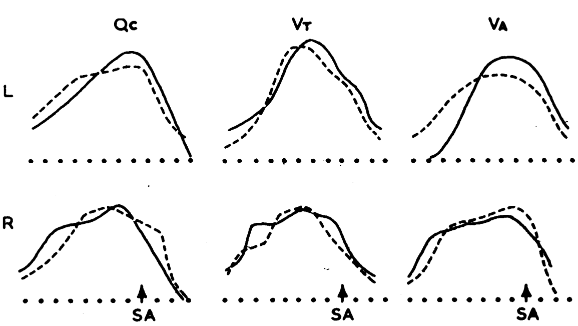

Fig. 5.—Case 8. Similar scan to that in Fig. 4, showing negligible change in the xenon scans following resection of a large bulla in the right lower zone. Pre-operation: continuous line. Post-operative: broken line.

ing with appropriate change in these parameters. The good results of surgery obtained in patients with lower-lobe lesions have been a striking feature. The clinical significance of this finding may become apparent when correlated at a later date with the different pathological types of emphysema. The observation has no statistical validity on these few patients.

Both the ^{133}Xe scans and the bronchial-flow measurements have been useful in confirming the radiological appearances and in making anatomical location more precise. In general there has been agreement between these methods, but the discrepan-

Table V.—*Regional Function in Selected Patients*

Case No.	Result	Radiological Localization	Site of Operation	Lobar Flow (ml./min.)					Conclusion from ^{133}Xe Scan	Comment
				R.U.L.	R.M.L.	R.L.L.	L.U.L.	L.L.L.		
1	Improved	L.L.Z. > R.L.Z.	L.L.L. (a) L.L.L. (b)	80 < 10	160 56	30 84	92 130	< 10 < 10	Reduced ventilation and perfusion of L.L.Z. and R.L.Z. Unchanged after surgery	Close agreement between x-ray appearance, bronchial flow, and ^{133}Xe findings, but improvement found in overall lung function
2	Improved	R.M.Z.	R.M.L. (a) R.M.L. (b)	100 110	< 10 < 10	< 10 60	—* —*	270 260	Reduced ventilation and perfusion of R.L.Z., which increased after surgery	Improvement in ventilation and perfusion corresponding with overall function
7	Improved	R.U.Z. L.U.Z.	R.U.L. (a) L.U.Z. (b)	< 10 < 10	98 91	42 124	48 28	40 42	Reduced ventilation and perfusion of both upper and right mid-zones. Improvement in right upper and mid-zones post-operatively (see Fig. 4)	Bronchial flow localized the increased ventilation to R.L.L.
8	Improved	R.L.Z. > L.L.Z.	R.L.L. (a)	42	140	< 10	70	< 10	Normal distribution of ventilation and perfusion. No change after operation (see Fig. 5)	No abnormality detected over R.L.Z. by ^{133}Xe scan, in contrast to x-ray appearance and bronchial flow measurements
13	Not improved	R.U.Z. > L.U.Z.	R.U.L. (a) R.U.L. (b)	25 21	84 —*	220 49	98 147	110 182	Reduced ventilation and perfusion to R.U.Z., which improved post-operatively	No post-operative change detected by bronchial flow measurements, in contrast to ^{133}Xe scan

*Unsatisfactory sampling.

cies shown emphasize the complementary nature of each procedure. In the assessment of patients with lung disease for surgery, as opposed to physiological research, the bronchoscopic technique is the more useful because it is on an anatomical lobar or segmental basis, rather than being topographical like the xenon, and because it is possible not only to measure the distribution of the tidal volume into different lobes but to assess the ventilation and blood-flow balance in them, as well as getting information about the mechanical changes in the lung at a lobar level (Hugh-Jones and West, 1960 ; McGrath and Hugh-Jones, 1963). The radioactive-gas studies, along with whole-lung tomographs, afford a valuable screening procedure, for the detection of areas with a poor blood-flow, before bronchoscopy.

A major difficulty has been the selection of patients suitable for operation. The recognition of the degree to which chronic bronchitis contributes to a patient's disability has been of the utmost importance. Further, the contribution of this factor to post-operative mortality has been indicated. We would consider any form of untreated bronchitis a contraindication to assessment or recommendation for surgery. On the other hand, we have shown that, in spite of gross disability and generalized emphysema, dramatic subjective and functional improvement may occur.

A further difficulty has been the assessment of the surgical result due to the variation in the procedures performed. As the appearances at thoracotomy do not necessarily confirm the expected radiological or regional functional findings, decision regarding the most suitable procedure must be decided when the lung is exposed. For this reason no clear recommendation for the type of procedure can be given at present.

Further investigation of mechanical events in the lung before and after surgery is required, particularly their relation to the presence of tracheobronchial collapse as observed on the spirogram and at bronchoscopy. Some standardization of the type of operation is clearly necessary in addition to careful pathological study of resected material to correlate the type of emphysema with the functional result.

Summary

An investigation was begun to assess the possible surgical alleviation of "irreversible" airways obstruction due to emphysema. Fifty-two patients were studied by clinical and radiological examination, together with general and regional lung-function tests. Twenty-four patients were submitted to operation for resection or plication of bullae or localized transradiant areas. Nine patients showed clear evidence of functional improvement. Subjective improvement correlated most closely with the simple ventilatory tests, though isolated cases showed more improvement in other parameters. A notable finding was the improvement in five out of six patients who had basal lesions. The problems of selection of patients, the type of operation, and the significance of the functional results are discussed.

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Mechanism of Growth and Rupture in Cerebral Berry Aneurysms*

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It has long been accepted that arterial hypertension and its frequent concomitant, atheroma, are important factors in the initiation, growth, and rupture of cerebral berry aneurysms (Crawford, 1959). Certainly both clinical (McKissock *et al.*, 1959) and necropsy (Crompton, 1964) consecutive series have shown about 60% of patients with ruptured aneurysms to be hypertensive by comparable, if arbitrary, standards. This is higher than the prevalence of hypertension in a control group of similar age distribution. However, there has been little investigation of the actual mechanisms of growth and rupture, and it has been widely assumed that, like a blow-out in a bicycle inner tube, the aneurysm must rupture when the strength of its thinning wall can no longer withstand the tension in it. The wall of an aneurysm, unlike an inner tube, is a living and metabolizing structure, able to add to and reinforce itself. Enlargement does not necessarily imply thinning.

Crawford (1959) stated that most aneurysms ruptured at 6 to 15 mm. diameter, that 64% of ruptures were at the fundus

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