Thorax (1956), **11**, 149.

BRONCHOGRAPHIC STUDIES AFTER RESECTION FOR PULMONARY TUBERCULOSIS*

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(RECEIVED FOR PUBLICATION OCTOBER 28, 1955)

The operation of pulmonary resection for tuberculosis is of such comparatively recent origin that, despite the wide extent to which it is being used, little is yet known of the conditions which subsequently obtain in the residual lung tissue.

It is well recognized that, in the absence of space-reducing procedures such as thoracoplasty, plombage, or diaphragmatic paralysis, over-distension of the remaining lung is an almost invariable sequel. Many workers consider that this may have two undesirable results: (*a*) ipsilateral reactivation due to direct traction on incompletely healed lesions, and (*b*) diminution in pulmonary function. Opinions, however, differ as to the degree of risk involved in the various kinds of resection and as to whether a space-reducing procedure, e.g., a corrective thoracoplasty, is necessary in all cases or whether it should be used only where a large amount of lung has been removed. There are no published accounts of attempts to study the problem on an anatomical basis.

A knowledge of the extent to which the remaining segments are separately affected by over-distension would appear to be essential in estimating the probability of reactivation of the foci in those segments. Is, for instance, a focus in the apical segment of the lower lobe more vulnerable after upper lobectomy than a focus in one of the basic segments? What part does the middle lobe or lingula (so commonly the site of small lesions) play in filling the dead space? In what manner does the upper part of the lung expand after a lower lobectomy? Or, after segmental resection, is the space filled only by the remaining segment or segments of the affected lobe, or do the other lobes also take part?

Our knowledge is also incomplete as to the pathology of over-distension: whether it is a simple stretching or whether it is (or is likely to become) a true pulmonary emphysema.

Lastly, nothing is apparently known as to the presence or otherwise, after resection, of kinking or other distortion of the bronchial tree with its attendant risk of pooling of secondary infection.

PURPOSE OF THE PRESENT INVESTIGATION

The present work was undertaken to determine how far answers to the above problems could be obtained by post-operative bronchographic study.

Four objectives were kept in view: (1) To determine to what extent and in what anatomical manner the remaining pulmonary segments fill the space after the various types of resection; (2) to study the nature and the degree of over-distension by observing the distribution of attenuation of the bronchial tree; (3) where a space-reducing procedure has been carried out, to consider its success in preventing over-distension; (4) to note the occurrence, if any, of kinking or other distortion of the larger bronchi.

INTERPRETATION OF BRONCHOGRAMS

The nomenclature used is the international one adopted by the Thoracic Society in 1950 (Report of the Thoracic Society, 1950).

Simon and Galbraith (1953) have described the bronchographic appearances in emphysema associated with chronic bronchitis, but their criteria are not applicable to the cases in the present series in which the over-distension is not only relatively rapid but is due to mechanical factors and not to the pathological changes resulting from long-standing infection.

We have been unable to trace any published work on this subject and have therefore evolved our own criteria for estimating from bronchography whether over-distension is present: (1) Narrowing and attenuation of the smaller bronchi

* This article is based on work which was awarded a senior prize in the South-West Metropolitan Regional Hospital Board's Research Competition for 1954.

with poor filling giving a spider-like appearance; (2) an open pattern in the bronchogram indicating a wider separation of the smaller bronchi than that normally found.

CLINICAL MATERIAL

The cases studied were not in any way selected but comprised all the resections passing through our hands over a period of one year.

These fell into the following groups:

I	Upper lobectomies (unassisted)	5
II	Lower ,, ...	16
III	Upper ,, (assisted*)	11
IV	Apico-posterior segmental resections ..	10
	Miscellaneous	7
	Total ..	49

PRESENTATION OF CASES

So far as displacement and distension of the residual segments are concerned, each of the groups set out above is considered separately.

The extent to which the bronchial tree is distorted after resection is dealt with later in respect of the 49 cases as a whole.

GROUP I

UNASSISTED UPPER LOBECTOMIES

This group consisted of 15 unassisted upper lobectomies (eight right, seven left). In these the distension and displacement of the residual lobe or lobes occurred as follows:

APICAL SEGMENT OF LOWER LOBE.—In one case this segment had been resected together with the upper lobe, leaving 14 cases for consideration. Eleven of these showed upward displacement of the apical segment which in nine cases was so marked that the segment was seen to be lying in a vertical position extending upwards to the apex of the thoracic cavity.

In 10 of the 14 cases some or all of the criteria of over-distension were present. Of the remainder, one had abnormally large basal segments (Case 3, P. R.), one had a history of pleurisy, one had a bronchiectatic and contracted apical segment, but in the fourth no cause could be found for the absence of displacement and distension. The subapical segment was present in eight cases and in five of these had moved slightly upwards.

See Cases 2. J.L., 3. P.R., 12. R.C.

BASAL SEGMENTS OF LOWER LOBE.—In nine of the 15 cases the basal segments were completely unaffected.

The remaining six showed displacement upwards and forwards of the anterior basic segment, five of these being the left-sided cases in which the lingula had been resected. The sixth case (Case 3, P. R.) was a right upper lobectomy in whom there was a temporary post-operative atelectasis of the middle lobe.

Four of the six cases showing displacement also showed distension of the anterior basic segment.

See Cases 3. P.R., 11. A.C.

MIDDLE LOBE.—In all the seven right upper lobectomies the middle lobe was displaced upwards. In five of these the displacement was most marked in the lateral segment, two of which passed vertically upwards to the apex of the thoracic cavity. In six cases this lobe was distended.

See Cases 2. J.L., 3. P.R.

LINGULA.—In all the three left-sided cases in which the lingula had been left, this segment showed extreme upward and backward rotation. In two of these the superior subsegment filled the position normally occupied by the posterior segment of the upper lobe, having rotated through an angle of approximately 150°. These two showed distension, but in the third, in spite of the displacement, distension could not be demonstrated.

See Cases 12. R.C., 13 W.S., 14. B.N.

CONCLUSIONS

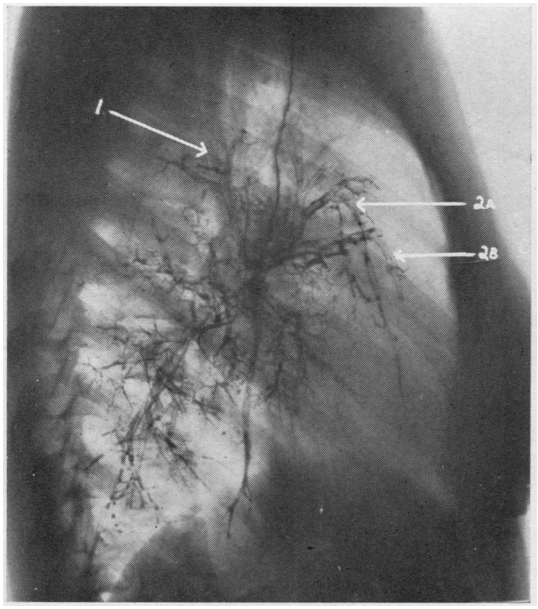
It is reasonable to conclude from these findings that in cases of unassisted upper lobectomy the apical segment of the lower lobe and the middle lobe or lingula (if not resected) are the parts of the remaining lung which by their upward displacement and distension fill the dead space.

The basal segments of the lower lobe are entirely unaffected except in left upper lobectomies where the lingula has also been resected. In these cases the anterior basal segment is displaced upwards and shows distension.

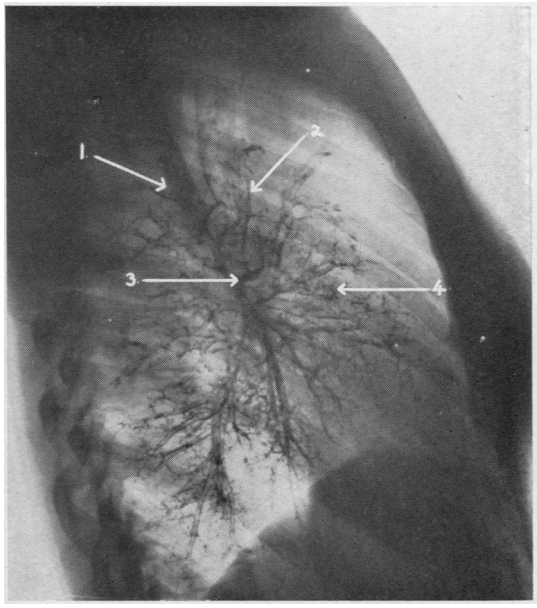
Harley (1954) has stressed the potential danger of any reversible lesions which may remain in the residual lung tissue. Bickford, Edwards, Esplen, Gifford, and Thomas (1952) had 10 such cases in which foci in the apex of the lower lobe reactivated after upper lobectomy without thoracoplasty. In no case did this occur when a corrective thoracoplasty had been carried out.

The findings in the present series would appear to explain these observations, and it is clear that residual disease in the apex of the lower lobe is at extreme risk of reactivation after upper lobectomy. A similar risk is entailed in respect of the middle lobe and lingula, especially the latter, where the displacement may be very marked. It therefore

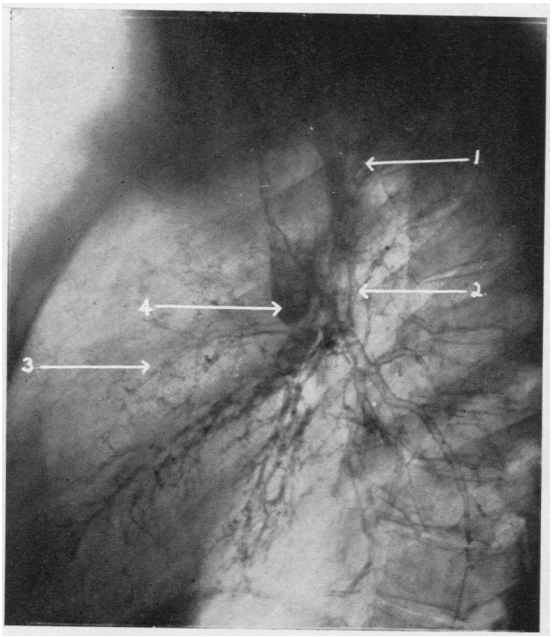
* The term "assisted" indicates that a space-reducing procedure has been carried out, and is used in this sense throughout the report.



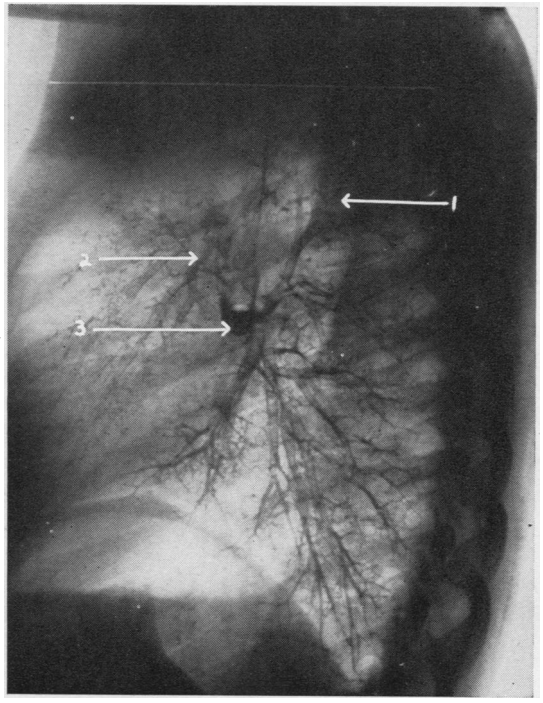
CASE 2.—J. L. Right upper lobectomy, unassisted. Lateral film: 1, apical segment of lower lobe. 2a, middle lobe, lateral segment. 2b, middle lobe, medial segment.



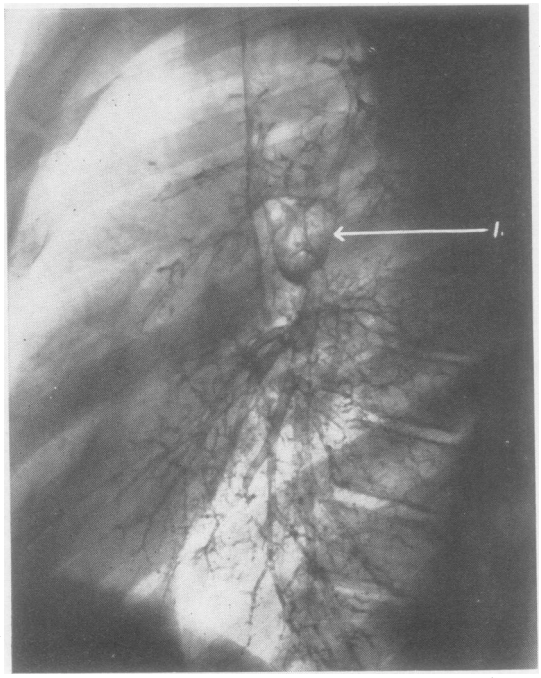
CASE 3.—P. R. Right upper lobectomy, unassisted. Lateral film: 1, apical segment of lower lobe. 2, middle lobe. 3, pooling in middle lobe stem. 4, anterior basic segment of lower lobe.



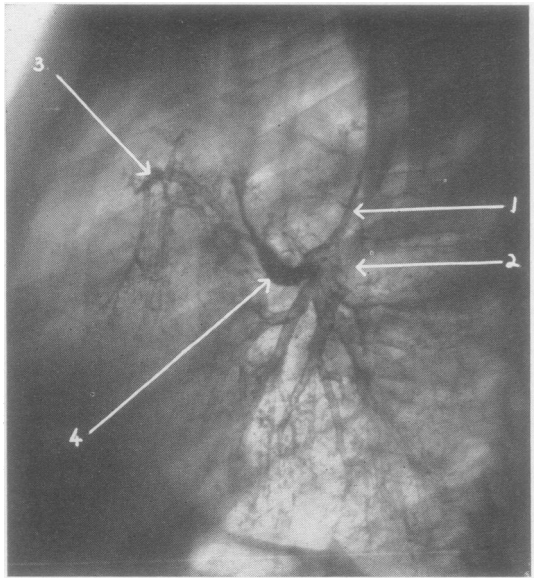
CASE 11.—A. C. Left upper lobectomy, unassisted. Lateral film: 1, apical segment of lower lobe. 2, subapical segment of lower lobe. 3, anterior basic segment of lower lobe. 4, pooling in main stem bronchus.



CASE 12.—R. C. Left upper lobectomy, unassisted. Lateral film: 1, apical segment of lower lobe. 2, lingular segments. 3, pooling in main stem bronchus.



CASE 13.—W. S. Left upper lobectomy and resection apical segment of lower lobe, unassisted. Lateral film: 1, lingula.



CASE 14.—B. N. Left upper lobectomy, unassisted. Lateral film: 1, apical segment of lower lobe. 2, subapical segment of lower lobe. 3, lingula. 4, pooling in main stem bronchus.

follows that a space-reducing procedure should be undertaken wherever resection of residual disease in these areas is not feasible.

GROUP II

LOWER LOBECTOMIES

There were six cases in this group, four right and two left lower lobectomies.

APICAL SEGMENT OF UPPER LOBE.—In all six the apical segment remained undisturbed with no distension.

POSTERIOR SEGMENT OF UPPER LOBE.—In four cases this was displaced downwards and in two remained undisturbed. In two cases only was there any distension.

ANTERIOR SEGMENT OF UPPER LOBE.—Five of the six cases showed downward displacement of this segment, very marked in one (Case 19, P. C.), where both lower and middle lobes had been removed. Here the lateral subsegment of the anterior segment had rotated downwards and backwards through an angle of nearly 180°.

Three cases showed distension, slight in one.

See Cases 18. P.B., 19. P.C., 20, J.G.

MIDDLE LOBE.—In three right-sided cases the middle lobe was displaced downwards, taking up a vertical position.

One case showed definite distension, one showed none, probably because a large upper lobe was present, and in the third distension was slight. In this case a phrenic crush had been performed. In the fourth, a right lower lobectomy, the middle lobe had been resected also.

See Cases 16. D.S., 18. P.B.

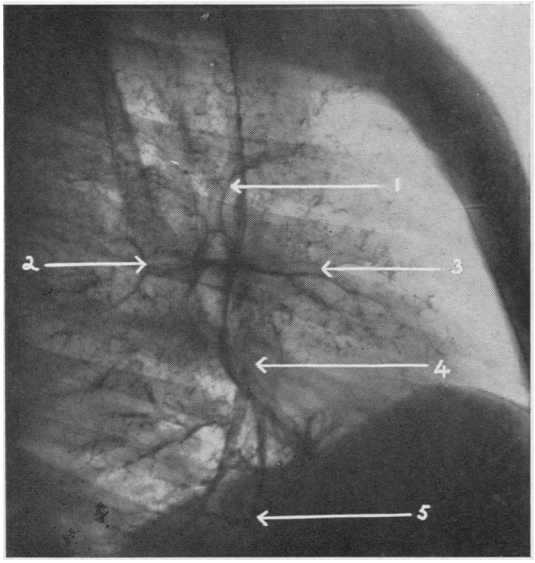
LINGULA.—In the two left lower lobectomies the lingula behaved in the same way as the middle lobe in the right-sided cases and was displaced downwards and backwards. Distension was present in both cases.

See Case 20. J.G.

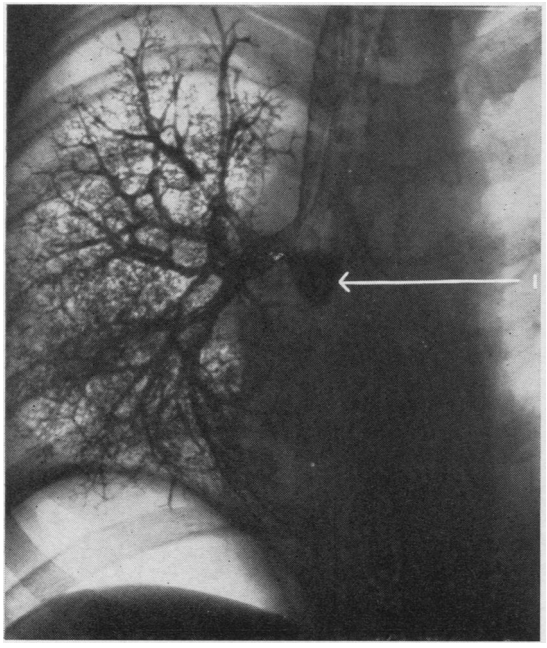
CONCLUSIONS

The middle lobe or lingula plays the greatest part in the filling of the dead space, but in no case is over-distension so marked as after upper lobectomy. Where the middle lobe or lingula fails to fill the space completely the anterior segment of the upper lobe and to a lesser extent the posterior segment is displaced. In no case is the apical segment of the upper lobe displaced or distended.

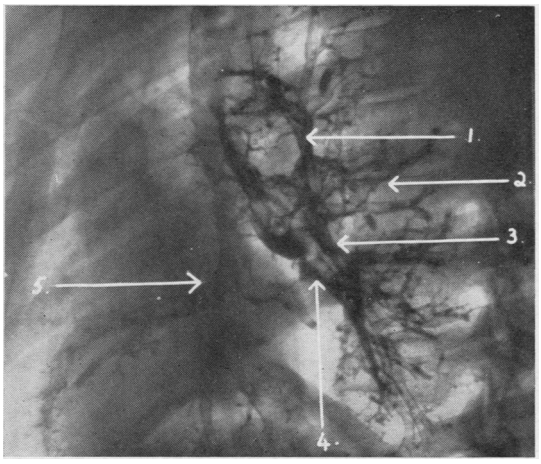
Over-distension of any part of the remaining lung is absent in the three cases with a raised diaphragm.



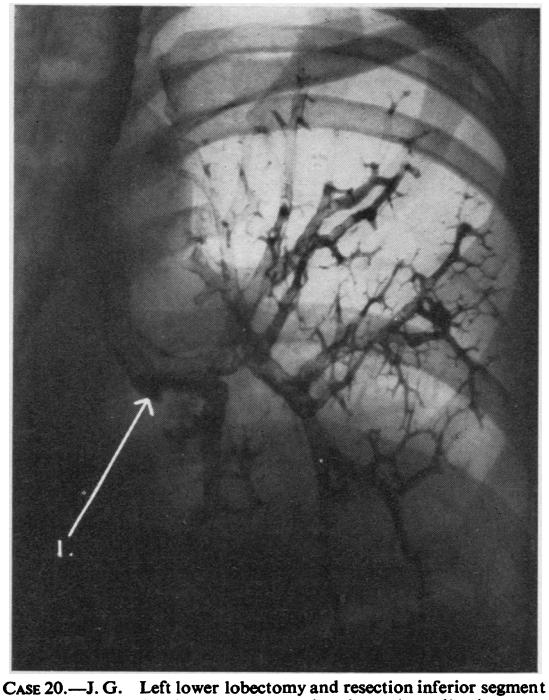
CASE 18.—P. B. Right lower lobectomy, unassisted. Lateral film: 1, apical segment of upper lobe. 2, posterior segment of upper lobe. 3, anterior segment of upper lobe. 4, middle lobe. 5, demonstrates backward hooking of middle lobe bronchi.



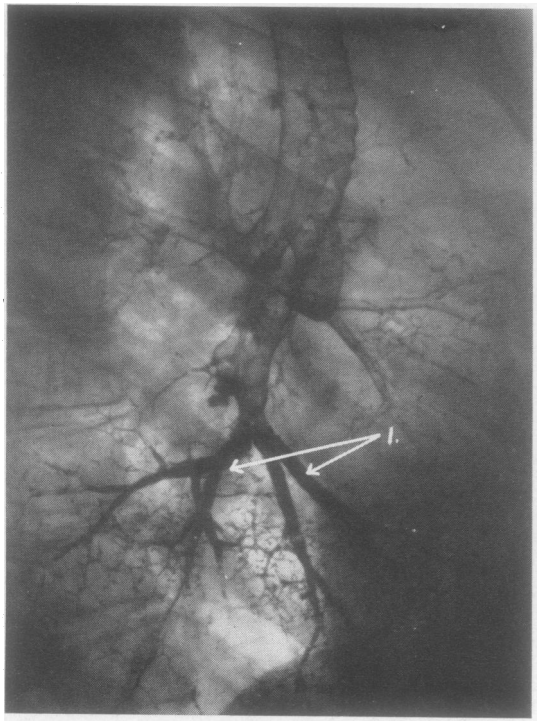
CASE 19.—P. C. Right lower and middle lobectomy, assisted. Postero-anterior view: 1, pooling in stump of lower and middle lobe bronchi.



CASE 20.—J. G. Left lower lobectomy and resection inferior segment lingula, unassisted. Lateral film: 1, anterior segment of upper lobe. 2, apical segment of upper lobe. 3, posterior segment of upper lobe. 4, superior segment of lingula. 5, spill-over.



CASE 20.—J. G. Left lower lobectomy and resection inferior segment lingula, unassisted. Postero-anterior view: 1, pooling in stump (lower lobe). Film shows generalized distension of remaining lung.



CASE 16.—D. S. Right lower lobectomy, unassisted. Lateral view: 1, Middle lobe showing downward and backward displacement and distension.

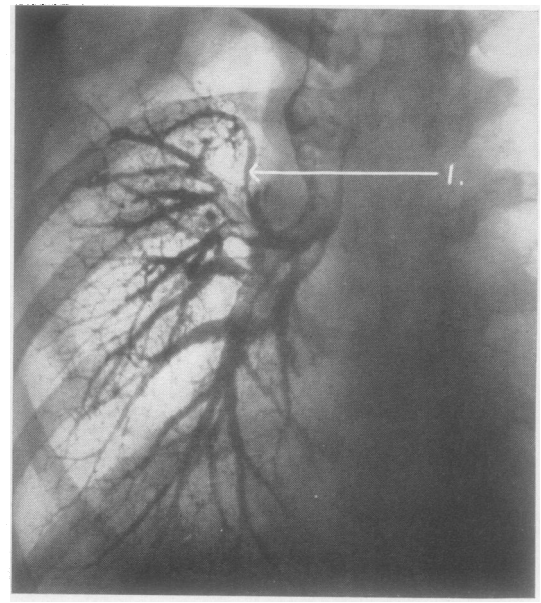
The series is a small one, but from these findings it would appear that residual reversible lesions in the apical segment of the upper lobe are not in danger of reactivation as the result of over-distension following lower lobectomy. If the lesions are situated elsewhere, particularly in the anterior segment of the upper lobe or middle lobe or lingula, there is a risk of overdistension, but this can be minimized by raising the diaphragm, i.e., by a phrenic crush and/or pneumoperitoneum.

GROUP III

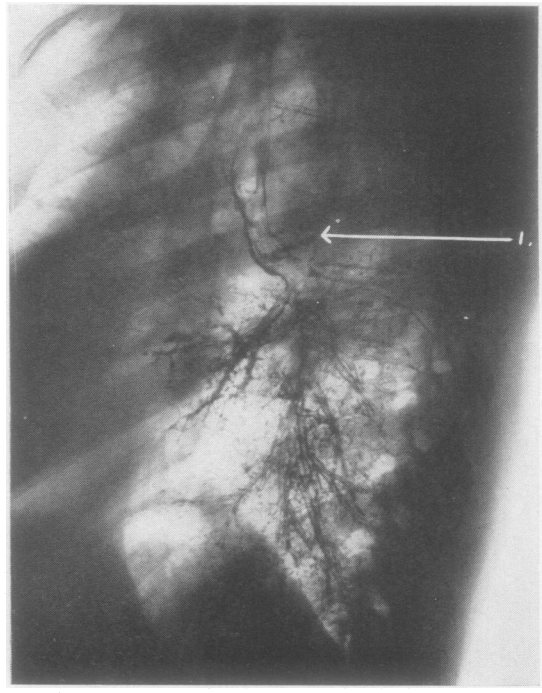
FIVE UPPER LOBECTOMIES ACCOMPANIED BY SPACE REDUCTION

APICAL SEGMENT OF LOWER LOBE.—In three of the five cases the apical segment had been resected. Of the other two the segment was undisturbed in one and in the other was displaced upwards and was distended. A subapical segment was present in three cases, being undisturbed in two and displaced upwards in the third.

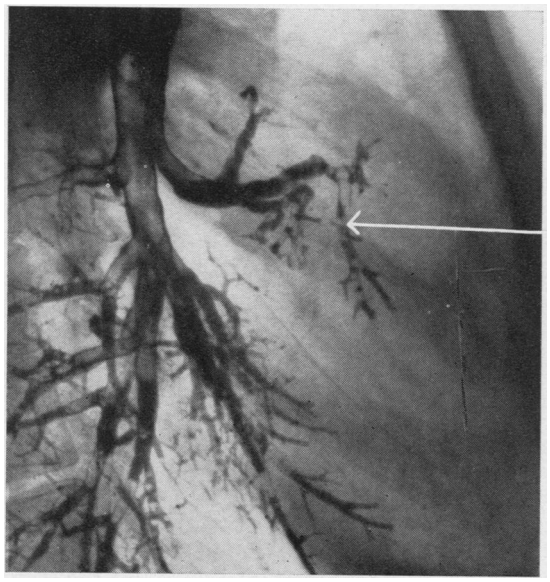
BASAL SEGMENTS OF LOWER LOBE.—In two cases all the basal segments were drawn backwards. In the other three they were unaffected. Distension was absent in all five.



CASE 24.—H. M. Right upper lobectomy and resection apical segment lower lobe, assisted. Postero-anterior view: 1, middle lobe.



CASE 25.—L. O. Left upper lobectomy, assisted. Lateral film: 1, lingula.



CASE 28.—N. K. Right upper lobectomy, assisted. Lateral film: 1, humping of middle lobe bronchi.

MIDDLE LOBE.—In all three right-sided cases the middle lobe was displaced upwards. In two the lateral subsegment was rotated into a vertical position. Distension was not marked in any of the three.

See Case 24. H.M.

LINGULA.—Of the two left upper lobectomies the lingula had been retained in only one, but here it showed a remarkable degree of displacement, having rotated upwards and backwards through 180°. Despite this range of movement, however, there was no distension.

See Case 25. L.O.

SIX UPPER LOBECTOMIES PRECEDED BY SPACE REDUCTION

In these cases a plombage had been performed at some former date in three and a thoracoplasty in the other three, but an upper lobectomy had subsequently become necessary either because of persistent cavitation or other evidence of activity.

LOWER LOBE.—The apical segment of this lobe and the subapical segment, where present, were all undisturbed.

The basal segments were undisturbed in two cases and crowded posteriorly in two. In the fifth there was forward retraction of the anterior basal segment. In the sixth the anterior basal segment was displaced forwards and upwards and the lateral and posterior basal segments backwards and upwards, but here the phrenic nerve had been crushed at the time of the resection.

Distension was significantly absent in five cases and was minimal in the sixth.

MIDDLE LOBE.—Of the two right-sided cases the middle lobe was undisturbed in one (as compared with the pre-operative bronchogram) and was drawn slightly upwards but not distended in the other.

See Case 28. N.K.

CONCLUSIONS

A space-reducing procedure, accompanying or shortly following an upper lobectomy, does not, contrary to what might be expected, prevent displacement of the residual lung. It is indeed still possible for either the middle lobe or lingula to swing upwards and backwards through a wide angle, as exemplified by Case 25, L. O.

When the lobectomy is performed after thoracoplasty or plombage displacement is, however, either minimal or absent.

What space reduction does appear largely to prevent is distension. This is present (and then only to a slight degree) in three of the 11 cases in Group III as contrasted with eight out of 10 cases in the unassisted series in Group I.

There must therefore be considerably less risk of reactivation of any residual lesions as a result of a space-reducing procedure.

GROUP IV

RESECTION OF APICO-POSTERIOR SEGMENTS OF UPPER LOBE (10 CASES)

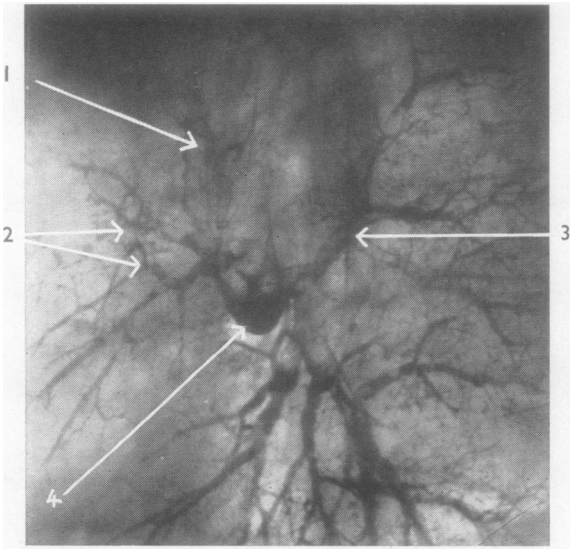
ANTERIOR SEGMENT OF UPPER LOBE.—In nine cases this segment was displaced backwards to a varying degree, and in three of these where the anterior segment was unusually large it filled the dead space completely. The tenth case had had a four-rib thoracoplasty and here the segment was undisturbed.

Five of the displaced segments showed no distension, three of these being the large ones mentioned above. The other four showed only some degree of distension.

See Cases 37. A.C., 39. G.B.

MIDDLE LOBE.—In one of the two cases there was no displacement because the space was filled by the large anterior segment. In the other the whole middle lobe was displaced upwards, the lateral segment assuming a vertical position. Neither showed any distension.

CASE 37.—A. C. Resection of posterior and apical segments of left upper lobe, unassisted (postero-anterior view).



CASE 37.—A. C. Resection of posterior and apical segments of left upper lobe, unassisted. Lateral film: 1, anterior segment of upper lobe. 2, lingula. 3, apical segment of lower lobe (very large). 4, pooling in main stem.

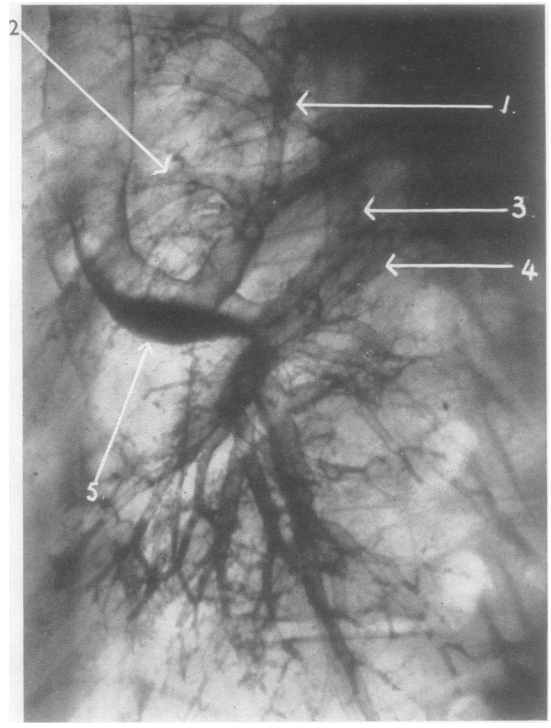
LINGULA.—In seven of the eight cases the lingula was displaced upwards, marked in five and slight in two, the latter being those with a large anterior segment. The eighth case was the one with a small thoracoplasty and here the lingula was undisturbed.

Four cases showed distension, but one of these had generalized hypertrophic emphysema, present pre-operatively.

See Cases 37. A.C., 39. G.B.

APICAL SEGMENT OF LOWER LOBE.—Where the anterior segment of the upper lobe failed to fill the dead space completely (seven cases) this segment was displaced upwards. In only two was there any appreciable distension.

See Cases 37. A.C., 39. G.B.



CASE 39.—G. B. Resection of apical and posterior segments of left upper and part of apical segment of left lower lobe, unassisted. Lateral film: 1, anterior segment of upper lobe. 2, lingula. 3, part of apical segment of lower lobe. 4, subapical segment of lower lobe. 5, pooling in main stem.

BASAL SEGMENTS OF LOWER LOBE.—The anatomy of the basal segments remained unaltered in all 10 cases.

Miscellaneous Segmental Resections (Seven Cases)

Six cases in this group consisted of a variety of resections, either of one segment alone or of one segment plus a wedge resection of another. In all of these the space-filling was carried out by the adjacent segments with no evidence of distension.

In the seventh case (Case 46, H. T.) where both the anterior segment of the right upper lobe and the middle lobe had been removed the whole of the lower lobe was uniformly distended.

See Cases 45 A.J., 46. H.T.

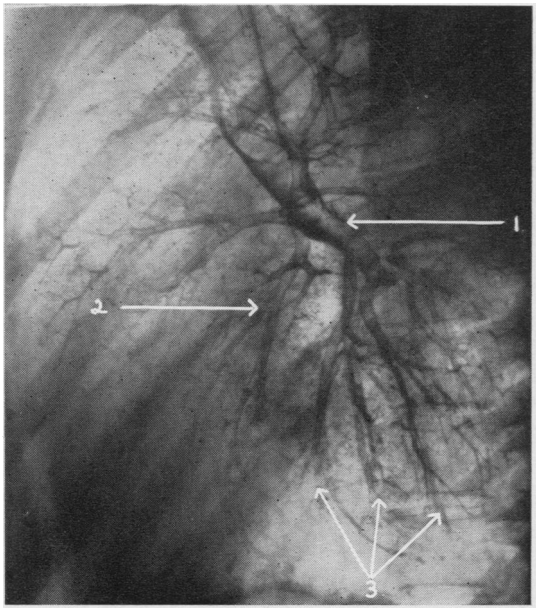
Conclusions

Where the anterior segment is large it is able to fill the dead space completely with no disturbance of the residual lung. Where this segment is smaller the space-filling is assisted by upward movement of the apical segment of the lower lobe and the middle lobe or lingula.

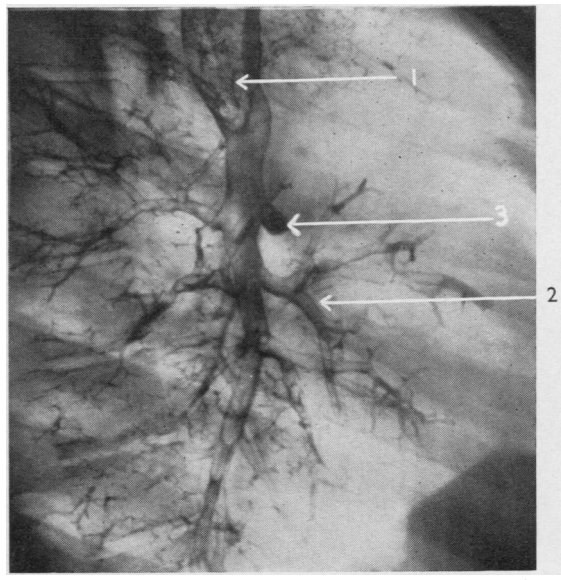
Distension is not marked in any of the cases and is clearly not a significant feature after apico-posterior resection.

Chamberlain and Klopstock (1950), after studying the changes in the anatomy of the pulmonary fissures by means of lateral tomograms, considered that "the presence of the anterior segment as a

Case 46.—H. T. Right middle lobectomy and resection of anterior segment of upper lobe, unassisted. Postero-anterior view: demonstrates uniform distension of lower lobe.



Case 45.—A. J. Resection of apical segment of lower lobe, unassisted. Lateral film: 1, main stem drawn backwards. 2, lingula, inferior segment. 3, basal bronchi drawn backwards.



Case 46.—H. T. Right middle lobectomy and resection of anterior segment of upper lobe, unassisted. Lateral film: 1, apical segment of upper lobe. 2, anterior basic segment of lower lobe. 3, pooling in middle lobe stump.

filler is thought to be extremely valuable to the function of the other pulmonary components. In segmental resection the degree of pulmonary distension is reduced and there is much less anatomic distortion of the tracheo-bronchial tree."

The present findings afford fuller and more accurate confirmation of this view in so far as the relative absence of distension is concerned. We have, however, shown that displacement of residual segments or lobes, not necessarily of functional importance, can occur and we also show later that bronchi may become markedly "kinked" after segmental resection.

DISTORTION AND POOLING

In addition to the findings already reported each of the 49 bronchograms was also examined to determine to what extent, if any, the bronchial tree becomes distorted after resection. It soon became evident that after certain resections changes may be found in the direction of the main stem and middle lobe bronchi, that pooling may occur in the stump, and that deflections of the smaller bronchi may also be present.

TABLE I

MAIN STEM AND MIDDLE LOBE BRONCHI

Type of Resection	No. of Cases	Main Stem				Middle Lobe
		Degree of Curvature and Pooling				
		Nil	Slight	Moderate	Marked	
Upper lobes (unassisted):						
Right ..	7	5	2	0	0	3 (slight)
Left ..	8	0	1	3	4	—
Lower lobes	6	6	0	0	0	0
Upper lobes (assisted)..	11	11	0	0	0	0
Segments, apico-posterior:						
Right ..	2	2	0	0	0	2 (slight)
Left ..	8	2	3	2	1	—
Segments, miscellaneous	7	5	2*	0	0	0

* These are Case 45, A. J. (apical segment of left upper lobe), and Case 49, C. F. (posterior segment and parts of apical and anterior segments of left upper lobe).

See Cases 12. R.C., 14. B.N., 37. A.C., 39. G.B., 45. A.J.

Pooling in the resection stump occurred in the lower lobectomies only and was seen in four of the six cases in this group (two on the right and two on the left)

See Cases 19. P.C., 20. J.G.

TABLE II

DEFLECTIONS OF SMALLER BRONCHI

Case No.	Resection	Deflection
2, J. L. ..	R.U.L. (unassisted)	"Humping" proximal third M.L. bronchus
8, B.McG.	L.U.L. (,,)	Hairpin bend lower lobe bronchus
14, B. N.	L.U.L. (,,)	Hairpin bend lower lobe bronchus. "Humping" proximal third lingular bronchus
17, P. M...	R.L.L.	Right-angled backward hooking of distal third of M.L. bronchi
18, P. B.	R.L.L.	As in 17, P. M., but more marked
28, N. K.	R.U.L. (assisted)	"Humping" medial M.L. bronchus
39, G. B.	Left A-P segment	Anterior looping of inferior branch of lingular bronchus

See Cases 2. J.L., 14. B.N., 18. P.B., 28. N.K., 39. G.B.

CONCLUSIONS

There is a variable degree of curvature of the main stem bronchus with pooling of "dionosil" after left upper lobectomy unassisted by space-reduction and also after resection of the apico-posterior segment of the left upper lobe. In all cases the direction of the curvature is upwards and backwards.

A similar but less marked condition of the middle lobe bronchus may be seen after unassisted right upper lobectomy and right apico-posterior segmentectomy, but the main stem bronchus on this side is rarely affected and then only slightly.

Angulations and curvatures of the narrower portions of the middle lobe and lingular bronchi may be seen after lobectomy, but are present in only one out of 17 segmental resections.

None of these changes has been observed after lower lobectomy or after upper lobectomy with space-reduction.

Pooling in the resection stump obviously depends on the length of the stump, which is a matter of surgical technique. It is noteworthy that in the present series such pooling has been seen only after lower lobectomy.

So far as can be traced, these observations have not previously been reported and their significance must be a matter of conjecture, but it is suggested that if "dionosil" may pool in this way so also may the products of infection—tuberculous or secondary. Repeated upper respiratory infections particularly may cause infected secretions to be deposited in these pockets with detriment to the

bronchial mucosa and the possible danger of spill-over.

Should the infection extend to the bronchioles and alveoli there must surely, in those cases showing deflections of the narrower bronchi, be greater difficulty in obtaining free drainage.

It must be said that these hypothetical complications do not appear to have been reported elsewhere, nor have they so far occurred in the cases under discussion, but it is possible that sufficient time has not yet elapsed for them to become evident. At the lowest valuation the present findings must be regarded as undesirable sequelae.

SUMMARY

Reviewing the series as a whole it would appear that after lobectomy unassisted by a space-reducing procedure the dead space is filled by displacement of the adjacent segments—sometimes to an extreme degree.

In the majority of these cases over-distension of the displaced segments is also demonstrable.

After segmental resection displacement follows a similar pattern but is much less marked and distension is negligible.

In cases of left upper lobectomy (unassisted) upward and backward curvature of the main stem bronchus with pooling is a constant feature, and also, but to a lesser extent, after apico-posterior segmental resection of the left upper lobe. These changes are rarely seen in the right-sided cases, but here the middle lobe bronchus may be slightly distorted.

Pooling in the resection stump may occur after lower lobectomy.

In the upper lobectomies with space reduction both distension and distortion are minimal. The middle lobe or lingula may, however, be displaced.

Sufficient time has not yet elapsed for the clinical significance of these observations to be fully assessed. It would, however, appear that a space-reducing procedure (major or minor) should be seriously considered in those cases of lobectomy where there is any suspicion of a residual reversible lesion in the segments of the remaining lung most likely to become over-distended. The value of a major procedure in preventing distortion of the main stem after resection of all or part of the left upper lobe is also stressed.

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