Post-mortem bronchography in the study of bronchitis and emphysema

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Many characteristic bronchographic features have been recorded in patients with chronic bronchitis but current interest is focused on the changes at the periphery of the bronchial tree (Freimanis and Molnar, 1960; Hirschfeld, 1961; Hirschfeld, Brantigan, Kress, and Goco, 1962). There are two reasons for this. Firstly, the small rather than the large airways are believed to be of major importance in 'obstructive' pulmonary disease. Secondly, some abnormal peripheral patterns described in chronic bronchitis may give a lead to the diagnosis of emphysema, including even the specific anatomical type.

Opportunities of examining lungs pathologically shortly after bronchography are rare, hence the need for a method of post-mortem bronchography which can be used to study radiological-pathological correlations and assist in interpreting bronchograms produced during life. This paper describes a method using airborne lead particles. Although this substance cannot be used in the living patient we chose it because lead, due to its high atomic weight, is sufficiently dense radiographically to produce a clear image of the finest air passages when they are merely coated on their surfaces. This was preferred to the solid filling obtained with liquid media, such as Microtrast or the mixture of Micropaque and gelatin used by Reid (1955a). Wyatt, Fischer, and Sweet (1961 and 1962) also chose a dry powder Micropaque microcrystalline barium sulphate. Sills (1962) used iodine vapour but judging from his illustration it is doubtful whether the peripheral structure is clearly shown. It is possible by our technique to ascertain accurately the level at which respiratory structure begins.

METHOD

CHOICE OF RADIOGRAPHIC CONTRAST MEDIUM. A substance was sought which would penetrate along the bronchial pathways to reach and outline the respiratory bronchioles but at the same time not produce such a heavy concentration in the alveoli as to obscure the anatomical details. Finely powdered metallic lead (2 to 15 microns) in an airborne cloud gives excellent results. The lead is commercially available as a powder, '100 mesh to dust'. The range of particle sizes in this product varies between different batches; only those with the finest dusts have been chosen. Finely divided lead is highly toxic if inhaled. Fortunately it soon settles from the atmosphere. The insufflation is done in a closed room, the operator wearing a face mask. The Seibe Gorman Mark IV industrial respirator holds back particles as small as 0·5 micron.

It is possible that other safer metallic powders could be used in place of lead, and current experiments are being carried out using precipitated bismuth (B.P.). This powder is insoluble in water and has no particles greater than 15 microns. The atomic weight is slightly higher than that of lead: Bi, 209; Pb, 207.

TECHNIQUE. The unfixed intact lung is suspended in a transparent negative pressure box (Fig. 1). (A range of cannulae is needed for tying into the main bronchi which have varied in this series from 1 to 1·5 cm. in diameter. The left lung is the easier to handle because of the greater extrapulmonary length of the left main bronchus.) Air-tightness of the apparatus and of the lung is important. Results have not been entirely satisfactory when a tear in the lung has required repair. The negative pressure applied to produce expansion of the lung has

![Transparent negative pressure expansion box.](http://thorax.bmj.com/)

172
been of the order of 20 cm. of water, although no harm has been observed when this figure has been doubled. Generally, pressures in excess of 20 cm. of water are required only to overcome the surface tension which is present between opposed alveolar walls at the time when the first expansion is attempted (McIlroy, 1952). The lungs are alternately expanded and then allowed to retract. The lead dust is insufflated into the bronchial cannula during expansion which simulates the inspiratory phase of respiration and the procedure is repeated over 15 to 20 cycles. A volume of approximately 2 to 3 ml. of dust is used but much is rejected by the lung at each deflation. It is important, particularly with emphysematous lungs, that adequate time is given between successive expansions to allow full collapse of the lung to occur. At the end of the procedure the lung is kept in expansion by plugging the cannula with a rubber bung.

**Insufflation of the lead powder** The lead is insufflated from a small metallic hand insufflator of the type commonly used for dusting wounds with therapeutic powders. Replacement of the rubber hand bulb by a supply of pressurized air is more effective in making the lead dust airborne but this has not usually been an advantage because, early in the procedure, the heavy load of dust clogs the moist bronchial pathway and prevents the finest particles penetrating to the periphery. Dispersion of the lead by a continuous supply of air under pressure from a pump or cylinder is reserved for cases where, due to tears in the lung or blocking of the air passages by mucus, the method using the hand insufflator has not been effective. Expansion of the lung in a negative pressure container then becomes unnecessary.

**Radiography of the specimen** For clarity of detail in the radiograph a fine grain film (Crystallex, a Kodak industrial X-ray film) has been used and an anode of small dimension (0.3 mm. focus). The films stand enlargement of five to 10 magnification without loss of detail. The radiographs have usually been taken with the beam passing coronally through the specimen, i.e., a lateral view. The usual exposure has been 30 mA, 50 Kv at 0-8 sec.

**Pathological correlation** After radiography the lung is fixed by filling it with 10% formalin solution rendered neutral or slightly alkaline with sodium bicarbonate, run into the main bronchus under low pressure, without subsequent clamping of the bronchi. The addition of bicarbonate is unnecessary in hard water areas; it prevents the slight solution of lead that occurs in soft water. After one week the lung is cut sagittally. The coating of lead powder on the bronchi and in the lung tissue is clearly visible when the lung is cut. The lead adheres to surfaces throughout the stages of histological preparation, i.e., paraffin embedding, cutting, and staining, aiding the task of relating features seen on the bronchogram to the anatomy. Slices of lung can be radiographed as a check. The lead does not interfere in any of the commonly used staining reactions (Figs. 2 and 4) and does not smear as Microtrast does.

Gough–Wentworth sections have been cut of the lungs examined. They provide an accurate record of bronchial abnormality and, in particular, of the presence or absence of emphysema.

**Results**

More than 30 lungs have been studied by the method described. Our aim has been solely to perfect the technique and collect for future study cases in which the clinical history enables us to judge whether the patients had chronic bronchitis as defined in the Ciba Symposium Report (1959). The lungs examined to date include six with emphysema. Three with widespread ‘vesicular’ emphysema (Heppleston and Leopold, 1961) are included and also two further lungs with local disease of the same type. (‘Vesicular’ is used to denote emphysema limited to the distal structures of the acinus, i.e., alveolar ducts and sacs and possibly distal respiratory bronchioles.) The sixth example of emphysema is the case of chronic bronchitis with emphysema of centrilobular type (Figs. 3 and 4). It was included so that we could examine a known case of clinically severe respiratory disease.

The illustrations show that the method gives clear definition of the bronchial and bronchiolar
pathways and, in some parts of the lung at least, respiratory bronchioles. The change in surface pattern from non-respiratory to respiratory pathways is striking and accurately depicts the point where alveoli commence. A fine dusting of lead on the surface of respiratory bronchioles results in the alveoli becoming discernible in the bronchograms. In passages heavily dusted with lead, as is often seen in the proximal respiratory bronchioles, the relatively few alveoli present at this level appear as domed protrusions from the main outline of the passage. In distal respiratory bronchioles, usually only the tissue between adjacent alveolar openings is dusted. At this level alveoli are numerous and the shadow cast in the radiograph can be likened to a piece of wire mesh in which the openings represent the alveoli, and the places where the wire is twisted together represent the lead-dusted surfaces (Figs. 5, 6, and 7).

This report is of a preliminary nature but there are already noteworthy findings related to the peripheral parts of the bronchogram. A close similarity has been noted between in vivo 'peripheral pooling' and the circular shadows at the periphery of the post-mortem bronchogram in the only case of centrilobular emphysema occurring in this series (Figs. 3 and 4). Furthermore, bronchograms of normal lungs show that the central tissue of the lung contains fewer branches between the main bronchus and the first order of respiratory bronchiole than has been previously recognized. There may be only six branches (Fig. 7). This contrasts with the estimate of Reid (1958), who stated 'the shortest pathway which supplies the lung close to the hilum of the segment may have as few as eight'. Hayek (1960), quoting from two different sources, gives figures of nine and 11.

**DISCUSSION**

Bronchography has been used to demonstrate abnormalities in persons with chronic bronchitis but the pathological basis for some of these abnormalities has not been adequately studied. There is agreement among bronchographists concerning the changes at bronchial level which can be attributed directly to chronic bronchitis. Dilatation of small bronchi which may be local or generalized and sometimes apparent only in the films taken on inspiration has been described by

FIG. 3. Part of bronchogram of a slice of lung showing 'pools'. Male, 65 years, with bronchitis, clinical emphysema, and right heart failure. The circular expansions, terminating the branches of the bronchial tree, are finely dusted by lead powder. These expansions are centrilobular (respiratory bronchiolar) spaces of emphysema, × 3.

FIG. 4. Histological preparation of lung depicted in Fig. 3. Two small centrilobular spaces. The supplying bronchiole and periphery of right-hand space are outlined by lead particles. Near right edge is a lobular septum. H. and E., × 11.
Post-mortem bronchography in the study of bronchitis and emphysema

FIG. 5. 'Positive' and 'negative' representations of alveoli in lead dust bronchograms.

FIG. 6. Low-power magnification of the peripheral pattern in a bronchogram using lead powder, to show the distinction between respiratory and non-respiratory structure. Respiratory structures have a feathery or bossed outline because of the alveoli projecting from the walls, × 3.

FIG. 7. Upper anterior and lingular segmental bronchi of lung shown in Fig. 9. A central branch of the anterior bronchus divides only three times before respiratory bronchioles are outlined, i.e., six branches from the main bronchus, × 3.

FIG. 9. Post-mortem bronchogram, left lung. Woman of 56 years with chronic bronchitis. Widespread tubular bronchial ectasia. Compare with Fig. 8. × ½.


FIG. 11. Left lower lobe. Apical bronchus showing 'diverticulosis', × 2.
Bonnamour and Badolle (1929), Spark and Wood (1932), Christopherson (1933), and Simon and Galbraith (1953) (Figs. 8 and 9). 'Diverticula' of the bronchi were reported by Duprez and Mampuys (1953) and by Simon and Galbraith (1953) (Figs. 10 and 11). The difficulty of filling the smaller branches of the bronchial tree due to the presence of secretions gives the so-called 'broken bough' appearance.

Christopherson's (1933) publication, which was early in the application of bronchography to the study of bronchitis, showed changes in the peripheral part of the bronchogram. Interest in the changes at this level has increased within recent years and a variety of terms is used to describe the appearance, e.g., peripheral pooling, mimosa or lily of the valley patterns, and spider-like formations.

It is uncertain whether these terms describe appearances of identical or different pathology. However, Duinker and Huizinga (1962) suggest that the 'mimosa', 'lily of the valley' and 'spider' patterns are one entity, for which they now advocate the term of 'the flowers'. 'Pools' they believe are different. Proof of the correct interpretation of these patterns is awaited. Nevertheless, we firmly believe that all these changes in the peripheral bronchogram are more relevant to changes in the respiratory rather than in the non-respiratory structure because, in a lung which developed granulomata after bronchography with dionisol, the peripheral pools were shown to be due to the filling of centrilobular emphysematous spaces (Leopold and Seal, 1961). Reid (1955b) explained pools on the basis of saccular bronchiolar ectasia occurring proximal to the terminal bronchiole. Israels and Warringa (1961) called this type of disease 'gallnut' bronchiectasis. There are therefore two quite contradictory views regarding the significance of pools. Our view places their origin more distally in the bronchial tree than the view of Reid. Theoretically it might be considered of fundamental importance to note how many bronchial branchings occur proximal to the pools. The bronchogram showing peripheral 'pooling' published by Leopold and Seal (1961) has raised the question whether the pools could represent emphysematous spaces because they were entered by contrast medium after as few as six branchings beyond the main bronchus.

Our post-mortem bronchograms of normal lungs provide a satisfactory reply. They show that there may be as few as six branchings from the main bronchus to the first respiratory bronchiole along the non-axial pathways which supply the centre of the lung. We doubt that careful noting of the number of branchings proximal to the pools will necessarily be of help in distinguishing peripheral saccular bronchiectasis from centrilobular emphysema. Instead, in patients showing pooling we suggest the radiographs should be repeated five days to one week later. One can expect the usual mechanisms of bronchial clearance to remove the radio-opaque medium from ectatic non-respiratory bronchioles because ectatic changes at this level are rarely associated with metaplasia of the lining epithelium to a non-ciliated pattern. On the other hand, opaque medium, lying within centrilobular spaces, depends for its removal on mobilization by alveolar macrophages which will be slower and may be incomplete.

SUMMARY

Airborne lead particles were used to produce post-mortem bronchograms. The method has the special merit of outlining the bronchial tree to respiratory bronchiole level where the presence of alveoli projecting from the walls results in a distinctive change of outline.

The in vivo appearance of 'peripheral pooling' has been duplicated in the post-mortem bronchograms of a case of centrilobular emphysema. Bronchograms of normal lungs have shown far fewer branchings of the bronchial tree leading to respiratory bronchiole level in the central tissue of the lungs than has previously been recognized. There may be as few as six branches from the main bronchus to the first respiratory bronchiole.

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