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Increased Penetrability of X-Rays Through Normal Lung and Other Air-Infiltrated Substances.

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X-rays are absorbed by a substance through which they pass in proportion, first, to a power of the atomic weight and, second, to the mass of the substance penetrated. This principle is fundamentally concerned in clinical roentgenology, for it permits certain tissues to be distinguished from others on the roentgen-screen and film. The normal lung is a case especially in point. Its average atomic weight is less than that of bone and its mass per unit thickness is much less than that of the neighboring soft tissues, owing to its infiltration with air. The organ is, therefore, more radiolucent than its environs. When air leaves the lung completely and the tissues shrink together, as in atelectasis, the mass per unit thickness becomes approximately the same as that of other soft tissues and the organ may not be distinguishable by x-ray examination from them. However, during certain roentgenologic observations by one of us on specimens of atelectatic lungs, the contrast between the density of atelectatic and air-containing lobes seemed greater than it should be, if atomic weight and mass alone were responsible. The matter was put to the following tests:

A dog was operated upon surgically and the main bronchus of the accessory lobe was ligated. The animal was sacrificed 24 hours later. The lobe was removed and found to be totally airless and collapsed. It was packed into one end of a cardboard cylinder, 3.7 cm. in diameter and 12 cm. in length, and the cylinder was placed upon one quadrant of a roentgenographic film-casset with the lobes next to the casset. The other quadrants were covered with a lead sheet. The énsemble was brought beneath, and 65 cm. away from, a linical x-ray tube, so that the rays could pass longitudinally through the clinder onto the film, and an exposure was made. The cylinder was then inverted on an unexposed quadrant of the casset, with lead covering for the other quadrants, under the tube as before, and an exposure equal to the first was made. The lobe was removed, its bronchus was fitted with a cannula, and its parenchyma was fully aerated by blowing into the cannula. First allowed to deflate, the lobe was reinserted in the cylinder with the cannula protruding

from a window in the side; and it was inflated again, this time not quite completely but as fully as the cylinder allowed. The lobe then occupied about 5 times the length of cylinder formerly occupied. The cylinder and contents were placed upon a new quadrant of the casset, with lead covering for the others, under the tube, and were x-rayed by the same dose. The film was developed. The shadows of the 2 poses of the atelectatic lobe (see A and B in the illustration) were approximately equal in density, and taken as a whole they were distinctly denser than the shadow of the lobe when air-containing (C). The experiment was repeated with another dog and very similar results were obtained (D, E, and F).

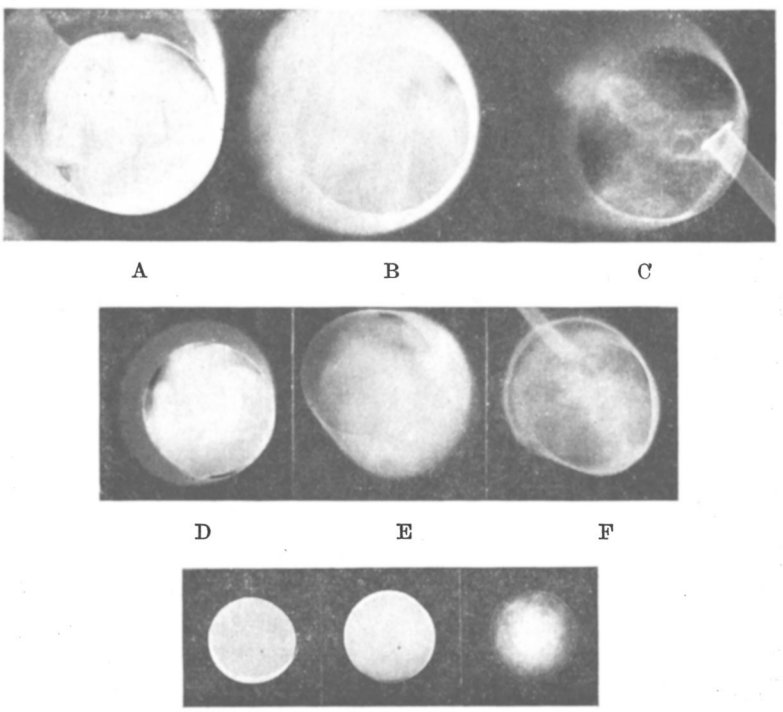

FIG. 1.
Roentgenograms of objects in paper cylinders: upper 2 rows are of lung lobes and lowest row is of glass objects. A, D, and G are of solid objects placed close to the film; B, E, and H are of the same taken a distance from the film; and C, F, and I are of the same close to the film and infiltrated with air.

A disc 0.7 cm. in height and 1.8 cm. in diameter was cut from a bar of glass. The adjacent part of the bar was heated and blown into large bubbles with extremely thin walls. The bubbles were crumpled into a fluffy mass. Two cylinders of the diameter of the

disc and 10 cm. in length were made from heavy paper; and the disc was placed in one end of one and an amount of the fluffy glass equal in weight to the disc was packed into the other. None of the glass sheets were allowed to lie longitudinally. The sheets formed a column 6 cm. high. Now the same roentgenographic procedure was carried out with these objects as described in the cases of the lung lobes. However, the distance of the tube was 175 cm. The result was that the shadows cast by the disc in its 2 poses (G and H) were about equal in density, whereas that from the glass sheets taken as a whole (I) was distinctly lighter. Several other sets of exposures of these subjects gave the same results. The difference in density in each set was not as great as that in each instance with the lungs.

The expansion which followed admission of air between thin septa of the substance, whether lung or glass, occurred in a vertical direction only, so that the same mass was presented to the passage of the rays before and after expansion. The atomic weight could not well have changed. Rearrangement of tissues and increased scattering of rays in the cases of the expanded objects are possible factors in determining the lighter shadows, but we have no adequate explanation of the modes of operation of these factors. The point seems to be demonstrated, however, that the shadows cast by air-infiltrated substances in roentgenograms are lighter than they should be considering only the atomic weights and the masses penetrated by the x-rays.

With the same point in mind, Prof. Wm. S. Halsted is quoted[1] as having called attention to the fact that gas bubbles in the gastro-intestinal tract are often represented in the roentgen-film by contrasts in densities that seem greatly in excess of the displacements of tissue by them. It is also a common observation that parts of chest wall overlying the body of air in cases of pneumothorax appear more transparent than they should considering their thickness.

[1] Holman, E., personal communication to the authors.