Dr. Chodosh: Because of the problems in measuring these properties in vivo, this has not been done and so the question can’t be answered.

Dr. Lyons: Does the cellular content of sputum have any influence on viscosity?

Dr. Chodosh: There seems to be a gross correlation between the number of cells and the properties of the sputum. In general, the more the cellular concentration the more the viscosity, although I have not completely analyzed my results on this variable.

Dr. Mitchell: Why is purulent sputum, which contains more cells, less viscous than mucoid sputum?

Dr. Chodosh: Purulent sputum contains not intact cells, but disintegrated cells and the properties of broken down cells might be entirely different from intact cells.

Dr. Long: Is sputum density an important factor in evaluating the properties of sputum?

Dr. Chodosh: Yes, it is important, but it is very difficult to measure because of the trapped air bubbles in the sputum. However, we have found that the specific gravity of the sputum is usually .986 and the density is usually very consistent among chronic bronchitis as a group.

Physico-Chemical Properties of Sputum in Reversible Airways Obstruction*

E. E. Keal, M.D. and Lynne Reid, M.D.

Excess bronchial secretion is an important factor in the reversible component of airways obstruction associated with asthma and chronic bronchitis and particularly in status asthmaticus. Using freshly collected samples, two instruments have been used to investigate the physical properties of sputum. The Weissenberg rheogoniometer utilizes oscillatory movement to cover the range 0.01 to 1 s⁻¹. At this low shear rate, the steady fall in viscosity is interrupted by a notched plateau which always occurs over the same range of shear rates and is independent of the absolute viscosity. It is abolished by shearing, but at the same time there is an increase—up to five-fold—in the viscosity at the lowest shear rates. This is more marked in purulent than in mucoid sputum. Following mild shearing there is a time related factor, most marked in mucoid sputum, whereby the viscosity at lowest shear rates may be increased up to 80-fold when the specimen is allowed to remain between the platens for one hour. This not only stresses the need for careful control of experimental conditions, but may reflect conditions in the bronchial tree when mild shearing is followed by stasis due to bronchial constriction. The increase in viscosity is not due to drying of the specimen, since deliberate drying to 50 percent by weight only doubles the viscosity.

For the study of many specimens in different disease groups we have used the Ferranti-Shirley viscometer and have correlated the results with the dry weight and neuraminic acid content of the samples. A highly significant correlation has been found between the five measurements obtained from the rheogram—the initial and terminal yield values, the Y spur, the area of the hysteresis loop and the apparent viscosity at 1350 s⁻¹. The Y spur was present in only 23 percent of specimens and shear thinning occurred over a wide range of shear rates 400 to 1500 reciprocal seconds. When specimens of different viscosity are compared, the lowest shear rates are more discriminatory.

The intraspecimen or aliquot coefficient of variation was never more than 30 percent, whereas that between patients in any disease group was 60 percent or more. There was greater variation between macroscopic types of sputum than between disease groups.

Sputum viscosity was related to the neuraminic acid concentration (p = <0.001) but also to the yield of dry macromolecular material (p = <0.001). This may reflect the degree of hydration of the sputum, an altered synthesis of glycoprotein, or the addition of a tissue fluid component.

A seasonal variation in the dry weight and neuraminic acid content of mucoid bronchitic sputum has been found. Over a three-year period, higher levels were found in the winter months and may be related to the increase in smoke and sulphur dioxide concentrations in the atmosphere at these times. During the last winter, sputum viscosity has been measured at monthly intervals in a group of 14 chronic bronchitics and related to the biochemical results and to the degree of airways obstruction. For the whole group of 72 specimens there was a significant inverse relationship (p = <0.01) between sputum viscosity and FEV₁/VC percent. In individual patients there was a direct relationship.

*From Brompton Hospital, London, England.
Discussion

Dr. Lyons: While the correlation in Dr. Chodosh's presentation between the ventilatory and the physical properties of the sputum was considered highly significant, it seemed to me low. Perhaps drugs were altering the properties of the sputum, while if not, perhaps altering the patient's symptoms and his ventilatory properties. The patients chosen for this study were in a double-blind drug study. I therefore have some doubts whether Dr. Chodosh's results had the consistency that is contended.

Dr. Chodosh: The correlation between the sputum and ventilatory capacity did exist independently of the drugs used.

Dr. Keal: I agree that the changes in the property of the sputum were not secondary to drugs, but were, in fact, spontaneous changes.

Dr. Middleton: Dr. Keal, is there a correlation between the neuraminic acid content and the number of cells present in mucoid sputum and have you looked for neuraminidase in the sputum?

Dr. Keal: We have not made any attempt to quantify the cell content of sputum and, therefore, I cannot answer the first part of your question. We have studied the neuraminidase content of the sputum because many organisms that attack mucosal surfaces produce neuraminidase. There may be an association between bacterial neuraminidase and the cellular neuraminic acid within the sputum.

Dr. Townley: In some of our in vitro studies, neuraminidase does not seem to affect the viscosity of sputum directly, but if sputum is pretreated with neuraminidase and then treated with a proteolytic enzyme such as trypsin, the viscosity would decrease markedly. Trypsin or chymotrypsin alone would not do this. This treatment seems to work on all asthmatic sputum.

Dr. Reed: Dr. Keal, does there seem to be any effect of Isuprel upon the viscosity of sputum?

Dr. Keal: I have not done this study, but others have found that isoproterenol increases the size of goblet cells.

Dr. Chodosh: Isoproterenol also seems to act as an expectorant and therefore actually aids in sputum removal.

Dr. Pepys: Is it possible to rehydrate dehydrated sputum in vitro?

Dr. Keal: It is, in fact, possible to rehydrate sputum in vivo by rehydrating the patient. Earlier workers have shown that a doubling of the fluid intake in such a patient could lead to a threefold decrease in sputum viscosity.

Biochemical Characteristics Affecting the Consistency of Bronchial Secretions*

A. D. Barton, Ph.D.; J. L. Powers, B.S.; Melvin Lopata, M.D.; and Ruy V. Lourenco, M.D.

In patients with chronic obstructive pulmonary disease, the bronchial secretions are frequently abnormal in quantity, composition and consistency. The resulting sputum, with its altered viscoelastic properties, may be responsible in part for the impaired mucociliary clearance demonstrated in our

*From the Department of Medicine, University of Illinois Abraham Lincoln School of Medicine, Chicago.

CHEST, VOL. 63, NO. 4, APRIL 1973 SUPPLEMENT