The Spirographic "Kink": A Sign of Emphysema

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The significance of the "kink" occurring in the early portion of the forced expiratory spirogram of some patients with obstructed airflow was investigated in 153 patients with chronic obstructive pulmonary disease or asthma. The kink, which is presumably due to airway collapse, is facilitated by the presence of emphysema, which results in loss of elastic recoil, a positive pleural pressure, high bronchiolar resistance, and structural weakness in the walls of the major airways. A significant reduction of carbon-monoxide diffusing capacity was used as the indicator of the presence of significant anatomic emphysema. Eighty percent (39) of 49 patients with the spiographic kink had a low diffusing capacity, whereas only 16 of those without the kink had significantly impaired diffusion. Seventy percent (39) of the 56 patients who had emphysema by this criterion demonstrated a spiographic kink. This test is, therefore, offered as a simple, effective, and widely applicable screening procedure for detecting emphysema, with a low incidence of false-positive results.

The presence of emphysema in patients with chronic airway obstruction is diagnosed by radiographic or pulmonary function studies. The abnormalities of pulmonary function indicating the presence of emphysema include reduction of carbon-monoxide diffusing capacity (DL), a decrease in elastic lung recoil with increased lung compliance, an increase of total lung capacity (TLC), and an increase in the ratio of residual volume (RV) to TLC. It has been demonstrated that an increase of TLC or of the RV/TLC ratio is not found exclusively in emphysema but may also be present in other conditions, such as chronic bronchitis and bronchial asthma. Loss of elastic lung recoil with increased lung compliance appears to be a fairly reliable finding in emphysema alone; however, these measurements involve relatively sophisticated techniques with moderate discomfort to the patient and are, therefore, not widely employed. The DL is more routinely determined and is apparently a reliable measurement of pulmonary emphysema. This study was undertaken to ascertain whether the simple forced expiratory spirogram might also provide a clue to the presence of emphysema. It has long been recognized that some patients with expiratory airflow obstruction have an acute angulation or "kink" in the early part of the forced expiratory spirogram produced by an initial rapid-flow segment followed by a sudden decrease in flow to a low, almost constant value throughout the rest of expiration. The significance of the kink has been previously evaluated, and a relationship to emphysema has been postulated but no definite correlation established. The purpose of this study was to investigate and clearly define this correlation.

Methods

The pulmonary-function data of 153 patients with chronic obstructive pulmonary disease or asthma studied in the pulmonary-function laboratory of the Hospital of the Albert Einstein College of Medicine, Bronx, NY, were reviewed. Patients with associated restrictive ventilatory impairment or evidence of pulmonary fibrosis were excluded in this selection. Pulmonary function tests were performed by commonly accepted methods, using a 13-L Benedict-Roth water-filled spirometer (Godart Pulmotest) and the helium-rebreathing method for spiographic and lung volume determination, and the breath-holding technique for determination of DL.

The forced expiratory spirogram was examined by one of the authors (H.S.) for the presence of an acute angulation or kink in its initial portion. Without any knowledge of the clinical diagnosis or pulmonary function data, patients were divided into two groups according to the presence (group A) or the absence (group B) of the kink. Representative spiromgrams are illustrated in Figure 1.

The DL was employed as a measure of emphysema. The standard error of the estimate of this measurement is 15.

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percent of the mean; and, thus, a DL value of less than 70 percent of that predicted was considered to indicate significant emphysema. The frequency distribution of DL expressed as a percent of predicted was compared in groups A and B, and the incidence of significant emphysema in the two groups was evaluated by the chi-square test. The predicted DL was obtained from the following two regression equations previously derived in this laboratory:

1. Male DL = 0.275(height) - 0.108(age) - 11.424
2. Female DL = 0.164(height) - 0.10(age) - 1.497

where height is given in centimeters and age in years.

In order to nullify the effects of varying airflow obstruction on the distribution of DL, patients were divided into groups with similar values for the mean forced expiratory flow during the middle half of the forced vital capacity (FEF25-75%), and the incidence of a kink in both groups A and B in each FEF25-75% range of 10 percent of the predicted value was recorded.

RESULTS

The results demonstrate that the spirographic kink occurred significantly more frequently in patients with impaired diffusion than in those with a normal DL. Figure 2 reveals a wide distribution of DL in both groups of patients with obstructed airflow, with some degree of overlap. The mean DL in group A (with kink) was 59.2 percent of the predicted value, while the mean DL in group B (no kink) was 99.4 percent of predicted. Furthermore, of the 49 patients in group A, 80 percent (39) had a significant reduction of DL (less than 70 percent of predicted); while of the 104 patients in group B, only 16 percent (17) had a significantly reduced DL. The difference was found to be significant by chi-square analysis ($P < 0.01$).

When the distribution of FEF25-75% in groups A and B was considered, it became evident that the flow rates of the two groups exhibited a somewhat different distribution, group A having lower flow rates. The mean FEF25-75% was 18.4 percent of predicted in group A (with kink) and 35.5 percent of predicted in group B (no kink); however, Table 1 clearly demonstrates that in the ranges of FEF25-75% considered, 63 percent (5/8) to 90 percent (29/29) of the patients in subgroups of group A had...
The diffusing capacity as measured by both the single-breath and steady-state methods has been demonstrated to correlate highly with the extent of anatomic emphysema as measured by postmortem examination,\(^6\) whole lung tomography,\(^6,5\) and loss of elastic recoil.\(^6\) It would seem reasonable, therefore, to use the DL as a reliable measurement of anatomic emphysema. Patients with pulmonary fibrosis, which might also reduce the DL, were excluded from this study.

Our results clearly demonstrate that most patients with obstructed airflow whose spiromgrams exhibited a kink had significantly impaired diffusion and presumably significant anatomic emphysema. Only 16 percent of group B patients (without kink) showed a DL of less than 70 percent of that predicted, whereas 80 percent (39) of those with a kink (group A) had a significantly reduced DL. Conversely, considering all cases with a DL less than 70 percent of that predicted, 39 (70 percent) out of 56 cases had spiographic kinks, indicating that the sensitivity of the spiographic kink to significant emphysema was 70 percent. The specificity of the kink for significant emphysema was 90 percent, since 87 out of 97 non-emphysematous subjects did not exhibit the kink. It should, therefore, be acknowledged that 30 percent of the cases of emphysema can be missed by this simple technique. Similarly, a small percentage (10 percent) of cases may be falsely labelled as having emphysema on the basis of finding a spiographic kink. Nevertheless, in view of the simplicity and universal availability of spiography, as compared to more complicated physiologic tests, the presence or absence of the kink can serve as a useful preliminary indication as to the probability of existing significant emphysema.

It becomes apparent from analysis of the distribution of the DL and flow rates that there is a greater degree of obstruction in patients with a low DL. The possibility that the kink might correlate best with severe obstruction, rather than impaired diffusion, was eliminated by demonstrating that in any FEF\(_{25-75}\) subgroup between 10 percent and 40 percent of predicted, a majority of group B patients (without kink) showed normal diffusion, whereas most group A patients (with kink) had significantly impaired diffusion. This would seem to clearly indicate that...
the spiographic kink is not merely a reflection of severely impaired flow rates but rather is indicative of low DL and, therefore, of emphysema.

Dayman\(^1\) studied the mechanics of airflow in health and emphysema. He described a patient with a clinical diagnosis of emphysema in whom forceful expiration resulted in a good initial rate of airflow, followed by a sudden decrease of rate resulting in an inflected spirogram. In order to explain these observations, an expiratory check-valve mechanism was postulated.\(^14\) After a small effort-dependent portion the spirogram was characterized by orderly deceleration of flow which could not be increased by augmenting the threshold pressure. Dayman\(^14\) attributed the constant flow to a check-valve narrowing of the cartilagenous large airways and accounted for the constant deceleration of flow by a linear decrease in pulmonary tension paralleling decreasing lung volume, as documented by Hyatt and associates.\(^15\) In order to explain the inflected spirogram seen in the emphysematous patient, it was theorized that because of a loss of elastic lung recoil, driving alveolar pressure could be maintained only by a positive pleural pressure; however, this positive pleural pressure also acted to constrict bronchioles, which were more easily narrowed because of loss of elastic support. This resulted in early collapse of bronchioles and a sudden decrease in airflow.

Gandevia\(^16\) studied the spirogram in patients with severe obstructive pulmonary disease. He observed that in some patients the forced expiratory spirogram showed an initial sharp deflection followed by an almost linear phase. This contour was obtained with forced effort but was often absent in the nonforced tracing or when an external resistance was added. Bronchographic examination revealed narrowing of major bronchi only in those patients with a spiographic kink; this was confirmed bronchoscopically. Gandevia\(^16\) postulated that the initial rapid phase was due to tracheal collapse. The exact location of the flow-limiting segment is debatable; however, using bronchial catheterization, pressure-measurement techniques,\(^17\) and cinefluorography,\(^18\) the limitation of flow appears to be due to collapse of the trachea or major bronchi, as initially observed by Gandevia.\(^16\) In general, the degree of collapse was observed to vary inversely with the forced expiratory volume in one second. The factors in emphysema which predispose to airway collapse include structurally weak bronchi\(^19\) on the one hand, and low elastic recoil and high bronchiolar resistance,\(^20\) which result in low intraluminal bronchial pressure, on the other hand.

Tammeling and associates\(^21\) disagree that the inflected spirogram is indicative either of airway collapse or of any particular pathologic entity. They concluded that the kink was an artifact due to inertia of the spirometric bell and could be seen in any patient with obstructed airflow. The results of our study refute this conclusion in that those patients with a normal DL rarely demonstrated a spiographic kink, even though they might have severe obstruction. The point is that the deceleration of flow in emphysema is more rapid than in other conditions with comparable obstruction because of the unique combination of a decreased elastic lung recoil, a high bronchiolar resistance, excessive positive pleural pressure, and weakening in the structure of the walls of the trachea and major bronchi. Although any one of these conditions, if severe enough, could conceivably cause airway collapse and abrupt deceleration of flow, one seldom encounters a single defect of sufficient severity to kink the spirogram. Only in emphysema do all of the appropriate conditions coexist for kinking to occur with any great frequency. Thus, as demonstrated in this study, only those patients with both impaired DL and flow rates exhibited frequent spiographic evidence of airway compression.

### References

Smoking
Some of its Less Publicized Sequels

A single puff of cigarette smoke is 35 ml. If the smoke of well over 100 billion cigarettes—the daily consumption in the United States—could be synchronized and conglomerated at one site, it would create a fitting distress signal symbolic of the magnitude of national health hazard of smoking. Obviously, even though millions have given up smoking, consumption of cigarettes is still on an extremely high level. According to authoritative reports, in the United States men over 25 are smoking less but this decline is counteracted by increase in smoking among teenagers and women. The subject of this writing pertains to 33 percent of women of child-bearing age who are smokers. In particular, items related to pregnancy, neonates and related topics will be presented. They represent valid indictment of smoking, based on substantial corpus delicti. Tokuhata, CK of the University of Tennessee (Arch Environ Health 17:353, 1968) recorded increased infertility and less frequent pregnancies in cigarette smokers. In his opinion, probably the ova are affected by smoking (prezygotic impairment of reproduction). Also, other studies with the Rubin insufflation test are suggestive of the adverse effect of smoking by interfering with ovum migration, ovum fertilization and ovum transfer at uterotubal junction into the uterus. Russel, CS et al (J Obst Gynec 73:742, 1968) noted increased occurrence of abortion, fetal death and stillbirth among smokers. Others state that the heavier the smoking the higher the rate of abortion. Also, Heron, HJ (New Zealand Mj 61:545, 1962) observed that neonatal mortality was higher in infants of women who smoked. It is thought that in one-half of infant deaths in the United States, low birth weight is an underlying or contributory factor. It was pointed out at the 1975 World Conference on Smoking and Health that 5 percent of stillbirths in the United States was caused by smoking. Fabia, J (Canad MA J 109:1104, 1973) found that the risk of perinatal death was 24 percent higher in smokers than in nonsmokers. Reports indicate that prematurity of neonates is twice as high in women who are moderate or heavy smokers as in nonsmokers. Respective causal factors include reduced weight of the fetus (the heavier the smoking the smaller the newborn), constriction of the blood vessels, reduced weight of the placenta: Haberman, JA (Nat Forum on Management of Smoking Problems, Chicago, 1968) reported that reduced placental temperature was found by thermogram during smoking a single cigarette by women in the last trimester of pregnancy; inadequate supply of oxygen because of high COHb concentration in the blood (the latter may reach 4-6 percent in moderate smokers and 12 percent in heavy smokers, in contrast to 0.82-1.24 percent found in urban population); Moechlin, S (Poisoning—Diagnosis and Treatment, New York, Grune & Stratton, 1965) states that iron and other heavy metals act as intracellular intermediate oxygen carriers; blockage of the latter within certain enzymes by CO results in intracellular hypoxemia; also, increased production of oxytocin, and early rupture of the membrane. Retardation of fetal growth by smoking has been observed in experimental animals and in humans. In gravid smokers the mean birth weight may be 6 to 8 ounces less than that of infants born to mothers who are nonsmokers. As a corollary it may be mentioned that MacCormack, WJ (Arch Ped 69:157, 1952) ascertained that smoking one cigarette caused destruction of 25 mg of vitamin C in the body. Vitamin C is essential for the synthetic processes of all cells and its lack lowers phagocytic activity of leukocytes. Butler, NR et al (Br Med J 4:573, 1973) found in a British National Child Development Study that children at ages 7 and 11 years manifested a deficit due to smoking. Those of mothers who smoked ten or more cigarettes a day were between three and five months retarded in reading, mathematics and general ability as compared with progenies of nonsmokers. Habituation to smoking is an extremely difficult challenge because more often than not the euphoria of smoking renders inveterate smokers oblivious of or indifferent to its hazards.

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