CHANGES IN MAXIMAL EXPIRATORY FLOWS AFTER POSTURAL DRAINAGE IN PATIENTS WITH CYSTIC FIBROSIS OR CHRONIC BRONCHITIS

by

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ABSTRACT

Clinically, postural drainage is recognized as an important adjunct to therapy in the nursing care of patients with cystic fibrosis or chronic bronchitis. Previous studies designed to test the efficacy of postural drainage in improving ventilatory function have given conflicting and inconclusive results. In this study flow rates measured from maximal expiratory flow volume [MEFV] curves were used to evaluate more precisely the efficacy of postural drainage in acutely improving lung function.

MEFV curves were obtained before, 5 minutes after, 15 minutes after, and 45 minutes after a 30-minute session of postural drainage, percussion, and vibration in 19 subjects, 9 had cystic fibrosis and 10 had chronic bronchitis. At 5, 15, and 45 minutes after drainage there were no significant changes in forced vital capacity [FVC], forced expiratory volume in one second [FEV₁], forced expiratory volume in one second to forced vital capacity [FEV₁/FVC] ratio, and small variable changes in peak expiratory flow rates [PEFR]. There were significant increases in isovolume flow rates near 50 percent and 25 percent FVC, measurements sensitive to changes in airway resistance in small peripheral airways. These data suggest that postural drainage was effective in mobilizing secretions out of the small peripheral airways.
CHAPTER 1

INTRODUCTION

Postural drainage is an important nursing procedure in the care of patients with cystic fibrosis or chronic bronchitis. It is often used in conjunction with other treatments in order to facilitate airway clearance of sputum so as to reduce and prevent further airway obstruction and ventilatory dysfunction. In the clinical situation where postural drainage is often used in conjunction with other therapeutic modalities (antibiotics, bronchodilators, breathing exercises, coughing and hydration), it is frequently cited by health professionals as an effective means of facilitating pulmonary clearance and improving ventilation. In terms of research, however, there are few controlled studies to validate or disprove the clinical assumptions made about postural drainage.

Cystic fibrosis and chronic bronchitis are both characterized by the production of large amounts of sputum (abnormal tracheobronchial mucus, often viscid and purulent). Due to the abnormal quality and quantity of their tracheobronchial mucus, individuals with either of these diseases have difficulty maintaining a normal balance between the rate of sputum production and the rate of pulmonary mucus
clearance. Two natural transport mechanisms for the removal of sputum are known: (1) cough transport or the sudden expulsion of material from the bronchi, and (2) mucociliary transport or a lining of cilia that beat in a serous layer with their tips propelling an overlying viscoelastic layer of mucus towards the larynx by a constant wave-like motion. Postural drainage positioning and chest vibration and percussion provide gravitational and mechanical forces that are thought to help the natural transport mechanisms clear the airways of excessive sputum.

One physiological change that occurs in individuals whose airway transport mechanisms are overwhelmed by excessive sputum is airway obstruction and a concomitant increase in airway resistance. The present investigation attempted to study the changes in airway resistance after postural drainage in patients with cystic fibrosis or chronic bronchitis by measurement of flow rates as calculated from a maximal expiratory flow volume [MEFV] curve.

The MEFV curve is a simple pulmonary function test that is easy to perform and is highly sensitive for the assessment of airway obstruction (Motoyama 1973). It is a curve obtained during a forced vital capacity maneuver when maximal expiratory flow [Vmax] is plotted against lung volume (see Fig. 1) (Bates, Macklem, and Christie 1971). The forced vital capacity maneuver is performed

Legend of the Curve: TLC = total lung capacity
RV = residual volume

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by having the subject inhale to total lung capacity and exhale as hard and fast and completely as possible, to residual volume. On this curve the following parameters can be measured: (1) forced vital capacity [FVC], (2) forced expiratory volume in one second [FEV₁], (3) forced expiratory volume in one second to forced vital capacity [FEV₁/FVC] ratio, (4) peak expiratory flow rate [PEFR], (5) instantaneous maximal expiratory flow when the lung is at 50 percent of its total lung capacity [Vmax 50], and (6) instantaneous maximal expiratory flow when the lung is at 25 percent of its total lung capacity [Vmax 25].

If postural drainage facilitates airway clearance of mucus obstruction, thus reducing resistance to airflow, it should be followed by an increase in Vmax at all lung volumes, as measured by the MEFV curve. If post drainage MEFV measurements show significant improvement over pretreatment control values, one can conclude that postural drainage is an effective form of therapy in cystic fibrosis or chronic bronchitis. In some individuals Vmax at 5 minutes after postural drainage may reveal an initial decrease from the control values, probably as a result of airway obstruction by the mucus which was mobilized from the more distal airways into larger central airways. Fifteen minutes or 45 minutes after drainage, Vmax may show significant improvement over control values due to further expectoration of mobilized sputum.
The two different subgroups of patients (those with cystic fibrosis and those with chronic bronchitis) were chosen in order to allow a comparison in terms of post-treatment improvements in MEFV measurements. The major cause of the obstructive process in cystic fibrosis is excessive secretions (Lorin and Denning 1971), whereas in elderly chronic bronchitis patients with mild emphysema the obstructive process is influenced not only by secretions but also by irreversible emphysematous changes in lung parenchyma (Bates et al. 1971). One might expect the individual with cystic fibrosis to exhibit a greater improvement in his posttreatment MEFV measurements than chronic bronchitis patients due to the possibility that a larger portion of the total obstructive process in cystic fibrosis is of a reversible nature in terms of excessive secretions.

By using the MEFV curve as the primary pulmonary function test, this investigation evaluated the clinical assumptions made about the efficacy of postural drainage therapy. The experimental data obtained will be of use to the health professional in assessing objectively the effect of postural drainage on airway obstruction in patients with chronic bronchitis or cystic fibrosis.
Statement of the Problem

What changes occur in flow rates after postural drainage in patients with cystic fibrosis or chronic bronchitis?

Purpose of the Study

The purpose of the study was to investigate a means of evaluating the efficacy of postural drainage by measuring postdrainage changes in MEFV curves in patients with cystic fibrosis or chronic bronchitis. An increased understanding by nurses and physicians of the effects of postural drainage can be expected to result in a more rational prescribing of the therapy.

Definition of Terms

Definition of the following terms is essential in this study:

Postural Drainage -- The gravitational clearance of airways and lung parenchyma by the assumption of six different postures for four to five minutes each (see Fig. 2). Each posture corresponds to specific segments of the lung. In this study postural drainage includes the following procedures:

1. percussion -- the chest wall (ribs only) over the area to be drained is percussed or clapped for one minute. The hands are always cupped and held rigid as the wrists move to clap the draining area.
Fig. 2. Postural Drainage Positions
2. vibration -- during the period of four to five prolonged exhalations through pursed lips, a downward vibrating pressure by the flat part of the hand is applied over each area being drained. It is accomplished by rigid flexion of the wrists and rigid extension of the elbows, as a fine vibrational tremor is started from the shoulders.

3. cough -- if the patient does not spontaneously cough after drainage, percussion and vibration of each segment, he is instructed to cough and expectorate the mobilized sputum.

Cystic Fibrosis -- It is an hereditary (autosomal recessive) disease of the exocrine glands and primarily involves the lungs, gastrointestinal tract and skin. In terms of the respiratory tract, this biochemical genetic defect manifests itself in the mucus secreting glands of the bronchus resulting in the production of copious amounts of viscid mucus that accumulates in and obstructs the airways. A vicious cycle occurs in which mucus obstruction leads to secondary infection, which leads to further mucus accumulation.

Chronic Bronchitis -- It refers to "the condition of subjects with chronic or excessive mucus secretion in the bronchial tree, the diagnosis being clinical and based on chronic or recurrent cough not attributable to other
conditions" (Fletcher 1959). The words "chronic or recurrent" refer to "occurring on most days for at least three months in the year during at least two years" (Fletcher 1959).

**Hypotheses**

1. In the total sample, five minutes after postural drainage there will be no significant change in FVC, FEV₁, FEV₁/FVC ratio, PEFR, Vmax 50, and Vmax 25, when compared to pretreatment control values.

2. In the total sample, fifteen minutes after postural drainage there will be an increase in FVC, FEV₁, FEV₁/FVC ratio, PEFR, Vmax 50, and Vmax 25, significant at the 0.05 level when compared to control values.

3. In the total sample, forty-five minutes after postural drainage there will be an increase in FVC, FEV₁, FEV₁/FVC ratio, PEFR, Vmax 50, and Vmax 25, significant at the 0.05 level when compared to control values.

4. Forty-five minutes after postural drainage the cystic fibrosis subgroup will demonstrate a significantly greater improvement (at the 0.05 level) than the chronic bronchitic subgroup in FVC, FEV₁, FEV₁/FVC ratio, PEFR, Vmax 50, and Vmax 25.

**Conceptual Framework**

Excessive sputum accumulation in the airways leads to airway obstruction and increased resistance to airflow.
If postural drainage facilitates mucus transport and clearance, it should be followed by an improvement in MEFV measurements. A summarization of (1) the physiology of mucus transport and how it is effected by postural drainage, and (2) the principles of airway resistance as measured by the MEFV curve will be presented.

Mucociliary transport involves the mucociliary escalator which extends from the larynx to the respiratory bronchioles (Bouhuys 1974: 37). There are two layers of mucus: (1) the overlying viscoelastic layer which acts as a transport layer because the tips of the cilia propel it proximally, and (2) the underlying serous layer which acts as a medium in which the cilia move and upon which the overlying viscoelastic layer "floats" (Parks et al., 1971: 103). Peripheral to the respiratory bronchioles lie the alveolar ducts and alveoli which are lined with a thin fluid film that moves particles by surface forces from alveoli into respiratory bronchioles for removal by the tracheobronchial mucociliary escalator (Green 1973: 110, Parks et al. 1971: 103).

Although studies have shown there to be no dysfunction of the large, proximal airways' mucociliary transport mechanism in cystic fibrosis, or chronic obstructive lung disease (Sanchis et al. 1973a, 1973b) some peripheral, focal, or discontinuous dysfunction may occur (Waring 1973: 682). It has been theorized that
very viscid sputum is harder to transport through the alveoli and airways (Matthews et al. 1973: 304-305) and that viral and bacterial infections may slow ciliary transport of mucus (Newhouse 1973: 332).

Postural drainage positioning, through the effect of gravity, is believed to help the alveolar film and the tracheobronchial escalator remove debris when it is overwhelmed by viscous, infectious sputum (Petty 1974: 92-93, Thacker 1971: 8-9). One proponent of percussion and vibration theorizes that they "literally shake loose secretions" (Egan 1973: 444). Many authors propose that vibrations alter pressures within the airways so as to dislodge mucus plugs (Foss 1973: 668-669). Observations by bronchoscopy under general anesthesia show that "vibrations given on expiration squeeze the secretions from the bronchioles into the larger bronchi" (Thacker 1971: 20).

Once excessive secretions are mobilized into larger proximal airways (by mucociliary transport and/or postural drainage) cough transport can assist the cilia in airway clearance. Direct bronchographic measurements suggest that large bronchi, but not small bronchi, are cleared by coughing (Marshall and Holden 1963). Physiological principles of cough and its alterations in disease also support the theory that cough is only effective in clearing airways from the level of the lobar bronchi to the thoracic tracheal outlet (Macklem 1974: 761).
Cough transport of secretions occurs by a sudden blast of expelled air on airway mucus (Parks et al. 1971: 517). Cough effectiveness depends on the velocity, or distance per unit time of the gas molecules. Velocity is determined by airflow rates and by the cross-sectional area (Macklem 1974: 761). Since the total cross-sectional area of each bronchial generation gets larger as one progresses toward the alveoli, velocities are greater in proximal airways than in peripheral airways. Thus, we can understand one reason why cough is more effective in clearing large proximal airways of secretions than in clearing smaller, peripheral airways (Macklem 1974: 761).

Another mechanism which determines cough effectiveness is dynamic compression of airways or the dramatic narrowing of the airway lumen during a cough that is attended by maximal expiratory airflow. Figure 3 demonstrates this mechanism. The airways are distended at the alveolar end because alveolar pressure \( P_{\text{alv}} \) exceeds pleural pressure \( P_{\text{pl}} \). Since alveolar pressure equals the sum of elastic recoil pressure of the lungs \( P_{\text{st(1)}} \) and \( P_{\text{pl}} \), it is greater than \( P_{\text{pl}} \). Pleural pressure is the pressure exerted on the outer walls of the airways. As gas flows toward the mouth, pressure drops to become equal to or less than \( P_{\text{pl}} \). The point along the airway where \( P_{\text{pl}} \) equals airway pressure is called the equal pressure point.
Fig. 3. Schematic Model of the Respiratory System During Maximal Expiratory Flow. -- From Burrows et al. 1975: 35.

Legend of Model:  
Pst(l) = elastic recoil pressure  
Palv = alveolar pressure  
Ppl = pleural pressure  
EPP = equal pressure point  
Vmax = maximal expiratory flow

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[EPP]. Points along the airway where Ppl exceeds airway pressure are called areas of dynamic compression. The length of the dynamically compressed segment is determined by the location of the EPP. The airways downstream from the EPP (towards the trachea) are dynamically compressed, and airways upstream from the EPP (toward the alveoli) are distended. Since the dynamically compressed segment has a decrease in cross-sectional area, linear velocity increases so that cough efficacy is markedly improved (Macklem 1974).

Obstructive airway disease is accompanied by an increase in large airway compressibility, so the EPP tends to be captured in large proximal airways at all lung volumes, resulting in a decrease in the length of the dynamically compressed segment. What follows is a decrease in cough efficacy on peripheral airway clearance, leading to retention of secretions. Obstructive airway disease also results in markedly reduced maximal expiratory flow rates. What follows is a decrease in velocity and a reduction in cough efficacy (Macklem 1974).

From the preceding discussion it becomes clear that, in the presence of excessive sputum production due to cystic fibrosis or chronic bronchitis, therapeutic intervention is needed in order to help the cough and mucociliary transport mechanisms clear the airways of mucus obstruction, thus decreasing airway resistance to airflow. Objective
assessment of the efficacy of postural drainage in reducing airway resistance and improving $V_{\text{max}}$ can be attained by recording MEFV curves before and after postural drainage.

An analysis of the MEFV curve provides for an understanding of the physiological basis for volume—flow relationships. When $V_{\text{max}}$ is plotted against lung volume during a forced vital capacity maneuver, airflow rises rapidly to a high level, the peak expiratory flow rate [PEFR], and then declines over the remaining 75 percent of the FVC (see Fig. 1) (Motoyama 1973: 335).

$V_{\text{max}}$ is determined by (1) $P_{\text{st}}(l)$ at corresponding lung volumes for $V_{\text{max}}$, and (2) the resistance of the airways on the alveolar side (upstream) of the EPP ($R_{\text{us}}$); such that $V_{\text{max}} = P_{\text{st}}(l)/R_{\text{us}}$ (Motoyama 1973: 336). $P_{\text{st}}(l)$ is equal to the driving pressure from the alveoli to the EPP (Mead et al. 1967: 95) and depends on the lung's elastic retractive force. In cystic fibrosis patients $P_{\text{st}}(l)$ has been shown to be normal (Landau and Phelan 1973: 593), although in chronic bronchitis patients with emphysematous changes in lung structure $P_{\text{st}}(l)$ may be irreversibly decreased (Bates et al. 1971: 35, 177). Assuming $P_{\text{st}}(l)$ to be normal in cystic fibrosis, any change in $V_{\text{max}}$ after postural drainage will reflect changes in $R_{\text{us}}$ (Motoyama 1973: 336). Although $P_{\text{st}}(l)$ may be abnormal in the chronic bronchitis patients, it is unlikely to
change during the procedure, thus any change in $V_{\text{max}}$ will reflect a change in $R_{\text{us}}$.

Resistance of the upstream segment can be markedly increased if airway calibre is reduced by (1) increased tone of airway smooth muscle, (2) edema of the airway mucosa, and/or (3) the presence of excessive sputum (Knudson 1972: 10). To emphasize the critical importance of the airway calibre's effect on resistance an equation for resistance $[R]$ in straight circular tubes was developed by Poiseuille, $R = \frac{8nl}{\pi r^4}$ (n = viscosity, l = length, r = radius). Halving the radius will cause a 16 fold increase in resistance (West 1974: 102-103). Thus, removal of secretions should result in an increase in airway calibre, a decrease in $R_{\text{us}}$, and, therefore, an increase in $V_{\text{max}}$.

MEFV curves not only quantify expiratory airflow retardation but they also allow for an assessment of $V_{\text{max}}$ at various lung volumes, so that the influence of small peripheral airway resistance may be viewed separately from the influence of proximal airway resistance. Conventional spirometry and oscillatory resistance measurements do not afford this advantage. Topographic location of the EPP varies with lung volume; it moves alveolarward as lung volume decreases (Knudson 1972: 13-14). As a result, at low lung volumes $R_{\text{us}}$ and $V_{\text{max}}$ will primarily
reflect the frictional resistance of smaller, more peripheral airways (Motoyama 1973: 336). At high lung volumes, the EPP is located in large proximal airways (Knudson 1972: 13). Thus at high lung volumes $V_{\text{max}}$ and $R_{\text{us}}$ will primarily be influenced by the frictional resistance of the large upper airways.

Postural drainage is designed to move sputum from lung parenchyma and small peripheral airways into larger central airways so that cough and mucociliary transport can more effectively clear the airways of sputum. What should follow is a decrease in airway resistance and an increase in $V_{\text{max}}$.

**Assumptions**

This study recognizes the following general assumptions:

1. Presence of sputum in the airways increases resistance to airflow.

2. There will be no change in $P_{\text{st}(l)}$ during the study.

3. Maximal expiratory flow rates on the MEFV curve reflect changes in $R_{\text{us}}$.

4. There will be no change in total lung capacity [TLC] during the study.

5. Due to the combined error inherent in the test procedure and calculated measurements, a parameter was
considered to show significant change only if the percent change was greater than 10 percent.

**Limitations**

This study recognizes the following limitations:

1. Generalizations can only be extended to the sample.

2. MEFV curves are an indirect measurement of resistance to airflow and can be affected by lung elastic recoil.
CHAPTER 2

REVIEW OF THE LITERATURE

A summarization of the literature pertinent to (1) facilitation of airway clearance by postural drainage, and (2) use of MEFV curves to measure airway obstruction to airflow will be presented.

**Facilitation of Airway Clearance by Postural Drainage**

Chapter 1 presented a detailed discussion of the proposed theoretical and clinical basis for the use of postural drainage as a facilitator of airway transport mechanisms. In terms of research, however, there are few controlled studies to validate or disprove the theoretical and clinical assumptions made about postural drainage.

The few investigations regarding pulmonary clearance mechanisms in patients with cystic fibrosis or chronic bronchitis are conflicting in their results. A better understanding of pulmonary clearance in such patients is necessary in order to provide a basis for studies of therapeutic intervention aimed at the elimination of secretions in such disease states. Sanchis et al. (1973a) assessed mucociliary function in a group of 19 patients with chronic bronchitis or emphysema. They monitored the
rate of removal of an inhaled radioactive aerosol from diseased lungs and compared the findings to clearance rates in nine normal adult nonsmokers. In a similar study the same investigators (Sanchis et al. 1973b) compared the rate of removal of an inhaled radioactive aerosol from the lungs of 13 cystic fibrosis patients with the rate of clearance from the lungs of 9 normal adults. In both studies clearance rates from the diseased lungs were close to or faster than clearance rates from normal lungs. In the diseased lungs, however, most of the radioactive aerosol was deposited centrally in large proximal airways, whereas in the normal lungs deposition was preferentially peripheral. Because of the proximal deposition of the aerosol in the diseased lungs, a greater proportion of it was removed by the proximal portion of the mucociliary escalator, and thus total lung clearance was faster than or equal to clearance in normal lungs.

In the cystic fibrosis group (Sanchis et al. 1973b) although there was no correlation between clinical severity of the disease and differences in clearance rates, the more severely affected children suffered from more frequent spells of productive cough than the mildly affected children. These data suggest the possibility that if mucociliary clearance is not as effective, cough may play "an important compensatory part in clearance of pulmonary
secretions and maintenance of a patent airway" (Sanchis et al. 1973b: 654).

As visualized on bronchography by Marshall and Holden (1963), however, cough clears large bronchi but not small bronchi. If it were possible to deposit radioactive aerosol in peripheral airways of diseased human lungs, assessment of the alterations in the rate of mucociliary and cough transport in peripheral and proximal airways would be possible. This measurement would be helpful in patients with cystic fibrosis or chronic bronchitis as one of the major sites of airway obstruction in cystic fibrosis and chronic bronchitis is the small peripheral airways (Bates et al. 1971, Mellins 1969).

Pavia, Thomson, and Phillipakos (1976) attempted to study the effect of a vibrating pad on bronchial clearance in ten subjects with obstructive lung disease by measuring the rate of clearance of an inhaled radioactive aerosol. Each subject was tested twice; once during a control period in which the patient lay for one hour on a couch that supported his trunk at 45 degrees to the verticle, and once during a treatment period in which the patient lay for one hour in the same position with a vibrating pad interposed between back and couch. It was concluded that since most of the aerosol was deposited in large central airways, no significant effect of vibration on the rate of removal of the aerosol was found.
Just as it is difficult to assess directly the function of transport mechanisms, it is also difficult to study directly the effect of postural drainage on these mechanisms. Some authors mention, but do not document, that one can directly visualize the mobilization of sputum when performing percussion during bronchography (Petty 1974: 93), or when performing vibration during bronchoscopy (Thacker 1971: 20).

A number of studies have assessed the efficacy of postural drainage in cystic fibrosis and chronic bronchitis by measuring such parameters as pulmonary function tests, arterial oxygen tension \([\text{PaO}_2]\), arterial carbon dioxide tension \([\text{PaCO}_2]\), return to normal body temperature during an acute febrile illness, and sputum volume and rheology. Anthonisen, Riis, and Anderson (1964) recorded body temperature, sputum volume, \text{PaO}_2, \text{and PaCO}_2 in 63 patients with acute exacerbation in chronic bronchitis. Patients were randomly divided into two groups—the treatment group which received chest physiotherapy, and the control group, or those who did not receive chest physiotherapy. In the treated group the average time taken by the patient to regain a normal morning temperature was 5.1 days, in the control group it was 5 days. There was no significant difference between the average daily amount of sputum expectorated, the \text{PaO}_2 or \text{PaCO}_2 in the treated group and control group.
Peterson et al. (1967) measured return of body temperature to normal during an acute febrile illness, \( \text{PaO}_2 \) and \( \text{PaCO}_2 \), pulmonary function tests, daily sputum volume, and ventilation-perfusion on 43 patients with acute exacerbations in chronic bronchitis. Patients were divided into four groups; mild and severe cases were homogenously distributed. Group A was a control group that received a placebo medication; group B received chest physiotherapy; group C received potassium iodide, and group D received chloramphenicol. There were no significant differences among the four groups with respect to improvements in the parameters measured. The groups were comparable in terms of age (mean age 61), sex, and duration of illness, but their numbers were small. Most of the pulmonary function tests showed no significant change after the period of treatment, possibly a reflection of the irreversibility of lung disease and/or lack of specificity and sensitivity of the tests to changes in airway obstruction.

March (1971) measured sputum volume and forced expiratory spiromgrams in 20 patients with COPD before and after postural drainage. Sputum volume was measured during and for a 30-minute period after treatment. There was no significant improvement in pulmonary function and there was no correlation between the amount of sputum produced and the change in lung function. The postural
drainage treatment did not include percussion or vibration.

Lorin and Denning (1971) measured volume and consistency of sputum obtained during postural drainage in 17 children (age 6-24 years) with cystic fibrosis and varying degrees of lung involvement. Patients were randomly divided into two groups, those who had a 20-minute period of postural drainage, and the control group who coughed and expectorated sputum every 5 minutes for 20 minutes. The treatment group expectorated significantly more sputum than the control group. Group differences were not well documented in terms of severity of pulmonary involvement.

Tecklin and Holsclaw (1975) did spirometry before and 5 minutes after postural drainage, percussion and vibration in 26 subjects with cystic fibrosis. At 5 minutes after drainage they reported a statistically significant increase in PEFR, FVC, expiratory reserve volume [ERV], and inspiratory capacity [IC]. At 5 minutes after drainage significant changes in FEV₁ and maximal mid-expiratory flow rate [MMEFR] were not observed. The mean percent changes in PEFR and FVC were both less than 6 percent, changes which are of doubtful significance due to the degree of error inherent in the testing procedure.
Kang et al. (1974) measured FEV₁, sputum volume, subjective improvement and xenon¹³³ ventilation-perfusion studies before and after postural drainage with percussion in 15 subjects, 5 each with asthma, emphysema, and chronic bronchitis. The FEV₁ increased more than 15 percent in 8 of 15 subjects, and decreased in none. Statistical analyses and mean percent changes in FEV₁ were not given. After postural drainage the xenon¹³³ ventilation studies often indicated uneven changes in different parts of the lung. The lower portions of the lung fields showed more improvement than the upper portions.

Some authors have observed an increase in wheezing during the postural drainage procedure. Petty (1974: 107) listed increased bronchospasm as a contraindication to the use of percussion. Huber, Eggleston, and Morgan (1974), however, measured FEV₁ before and after postural drainage in 11 asthmatic children, and at 30 minutes after drainage the treated group showed up to a 40 percent increase in FEV₁ (mean was 11 percent). These results were compared to changes in FEV₁ in a control group, consisting of 10 asthmatic children who received no treatment during an equivalent interval. The control group showed a slight reduction in FEV₁ which the investigators attributed to the effect of repeated expiratory efforts. Data were not given concerning the incidence of
audible wheezes during the period of the study. The authors concluded that chest physiotherapy was not detrimental in asthmatic children and that it may be a useful adjunct to therapy. Tecklin and Holsclaw (1975) reported bronchospasm during postural drainage in 6 of 26 subjects with cystic fibrosis who had spirometry done before and after postural drainage, percussion, and vibration. The subgroup of 6 cystic fibrosis subjects with bronchospasm demonstrated similar results to the overall group. At 5 minutes after postural drainage both groups of subjects had statistically significant increased in PEFR, FVC, and IC, but the mean percent changes in these parameters were all less than 8 percent.

Motoyama (1973) assessed the effect of postural drainage on airway obstruction by measuring MEFV curves before, 5 minutes after, and 45 minutes after postural drainage in 10 patients with cystic fibrosis. Five minutes after postural drainage there was improvement in $V_{max}$ 25 and $V_{max}$ 50, significant at the 0.05 level when compared to pretreatment control values. In a few patients, however, $V_{max}$ initially (5 minutes after postural drainage) decreased from control values, probably as the result of airway obstruction by the sputum that was mobilized from small peripheral airways into large central airways. "In those patients $V_{max}$ improved after further expectoration"
Forty-five minutes after postural drainage there was significant improvement in VC, PEFR, Vmax 25, and Vmax 50 (Motoyama 1973: 342).

**Use of the MEFV to Measure Airway Obstruction to Airflow**

Recently, many authors are recognizing MEFV curves as highly sensitive tests for the assessment of airway obstruction. With this simple technique it is now possible to critically evaluate the degree of lower and upper airway obstruction and to assess the efficacy of various forms of treatment.

Many physiological studies have led to the clinical use of the MEFV curve. The first definitive study was that of Fry et al. (1954). They introduced the isovolume pressure flow curve which quantified aerodynamic behavior of the lungs at specified lung volumes. Their report demonstrated expiratory flow limitation or autoregulation; that is, as driving pressure was increased, expiratory flow rates increased to a maximum beyond which a further increase in pressure did not produce an increase in flow. Their description of the MEFV curve stimulated other investigators to search for the site of flow limitation and the mechanisms involved in autoregulation. Studies by Macklem, Fraser, and Bates (1963) identified that most of flow limitation occurs in airways of segmental size or larger. Their discovery was
consistent with the equal pressure point theory later advanced by Mead et al. (1967). Another concept of autoregulation was proposed by Pride et al. (1967). They modeled flow limitation after the autoregulation of flow achieved by a Starling resistor.

Along with these studies have been clinical investigations which show that the MEFV curve is a more valid and reliable way of studying expiratory flow events than is the spirogram, which plots volume against time. The MEFV curve contains the same information as the volume-time plot. However, the MEFV curve more readily allows quantitative analysis of flow at both high and low lung volumes during forced exhalation (Hyatt and Black 1973: 192).

Landau and Phelan (1973) did numerous pulmonary function tests on 46 cystic fibrosis patients and correlated the results with clinical severity. Tests used included: spirometry, MEFV curves, respiratory conductance, conductance of the upstream segment and frequency dependence of dynamic compliance [Cdyn]. The results suggested that the initial airway obstruction in cystic fibrosis is in the small airways. Cdyn was the most sensitive test for small airway disease, but since it involves measurements of transpulmonary pressures, it is not practical for routine testing. Vmax 50 was reduced in the majority of patients with frequency dependence of
Cdyn and this reduction in Vmax 50 correlated well with clinical severity. Spirometry tests tended to be abnormal only in more severely affected cases. Since small airways contribute a relatively minor part to the total airway conductance, there must be considerable alteration in them before measurements of respiratory conductance are significantly changed.

Gelb and Zamel (1973) measured MEFV curves and closing volumes on 9 patients with respiratory problems who had normal results on spirometry testing. MEFV curves were abnormal in all patients, especially at low lung volumes.

The above mentioned investigations are examples of numerous studies which provide data to support the validity and reliability of using MEFV curves to measure changes in airway resistance after various forms of therapy. Motoyama's (1973) preliminary investigation (results of which were discussed above) utilized the MEFV curve to evaluate the effect of postural drainage on airway obstruction in 10 cystic fibrosis patients. Controlled studies utilizing this technique are still needed.

**Summary**

Investigations pertinent to airway clearance, postural drainage and MEFV curves were reviewed. Cough and mucociliary transport mechanisms in cystic fibrosis and chronic bronchitis are not thoroughly understood. Studies
on these patients designed to test the efficacy of postural drainage in facilitating airway transport of excessive secretions gave conflicting and inconclusive results. Many of them lacked adequate controls and some of the pulmonary function tests used may have been insensitive to small changes in airway resistance. The MEFV curve has been shown to be a valid and reliable test for the indirect measurement of changes in airway resistance. With this technique it is possible to critically evaluate the degree of upper and lower airway obstruction and to assess the efficacy of various forms of treatment.
CHAPTER 3

METHODOLOGY

Research Design

An experimental research design was selected to study the effect of postural drainage in cystic fibrosis and chronic bronchitis. Because of the variability between individual subjects, each was used as his own control and the data were analyzed in terms of percent change from baseline. A pretreatment measurement of pulmonary function, the MEFV curve, was obtained as the baseline or control value on each subject. After the postural drainage treatment, MEFV curves were obtained at 5, 15, and 45 minutes.

The research proposal and the Subject Consent form (Appendix A) were submitted to and approved by the Human Subjects Committee. A letter of their approval appears in Appendix B.

The Sample

Nine patients with cystic fibrosis and ten patients with chronic bronchitis were selected from two southwestern hospitals. The subjects who agreed to participate and who met the criteria described below were included in the study.
Criteria for inclusion in the study were that the patients:

1. were diagnosed as having cystic fibrosis or chronic bronchitis;
2. were currently having a productive cough;
3. were able to follow instructions;
4. were physically able to tolerate postural drainage and pulmonary function testing;
5. had previously, or were presently doing, postural drainage as part of their treatment regimen;
6. had previously done a forced expiratory maneuver;
7. were willing to abstain from postural drainage for at least six hours prior to the treatment period;
8. had not received positive pressure breathing treatment, bland aerosol or aerosolized bronchodilator treatment for at least four hours prior to the treatment.

Upon meeting criteria one through six, the purpose and nature of the study were explained and the patient was asked if he would be willing to participate. Patients consenting to participate were informed of what their participation would involve and were given the Subject Consent Form to sign.
Method of Data Collection

Upon consenting to participate in the study the subject was told to abstain from using aerosol and positive pressure breathing treatments for at least four hours prior to the study procedure and to abstain from postural drainage for at least six hours prior to the study procedure. The subject was told to continue to take his routine oral bronchodilator medications.

The following treatment protocol was performed on each subject:

1. Subjects were instructed in the performance of a forced vital capacity maneuver.
2. Immediately before postural drainage MEFV curves were done by the subjects and were photographed by a polaroid camera from a storage osciloscope that was attached to a number four pneumotachograph with a volume integrator. FVC and FEV₁ were recorded from the volume integrator. The best of three readings was used.
3. Postural drainage was performed in the following manner:
   a. Subject assumed each drainage position for five minutes. The six positions were assumed in order from A to F, making a total of 30 minutes (see Fig. 2).
   b. Immediately upon the subject's assumption of a position the investigator began one minute of percussion over the area being drained.
c. After percussing the area, the investigator vibrated the area for a period of four prolonged exhalations.

d. If the subject had not coughed and expectorated sputum, the investigator instructed him to cough.

e. Subject remained in the position for the remainder of the five minutes and was allowed to rest for short intervals as needed.

4. Expectorated sputum was collected in a graduated container during the period of postural drainage and for the 45-minute period after postural drainage.

5. Five minutes after, 15 minutes after, and 45 minutes after postural drainage, step two was repeated.

6. Pertinent data from the subject's chart and information concerning sputum and respiratory therapy were recorded on the data collection sheet (see Appendix C).

7. FVC, FEV₁, FEV₁/FVC ratio, PEFR, Vmax 50 and Vmax 25 were calculated from the photographed MEFV curves and results were recorded on the data collection sheet.

**Method of Data Analysis**

The data were analyzed in terms of percent change from baseline. Those parameters demonstrating a change of greater than ten percent were statistically analyzed as described below.

For Vmax 50 and Vmax 25 T-tests for differences between groups (Walker and Lev 1953: 157) were done in
order to test for significant differences between the mean percent changes in the cystic fibrosis subgroup and the mean percent changes in the chronic bronchitic subgroup, at 5, 15, and 45 minutes after postural drainage. If these T-tests for differences were nonsignificant, the cystic fibrosis subgroup and the chronic bronchitic subgroup were then analyzed as one combined group. The combined group data were then subjected to an analysis of variance (Dunn and Clark 1974: 69) in order to test for differences with respect to time. If the analysis demonstrated a significant increase with time, standard T-tests (Walker and Lev 1953: 153) were then done to determine the specific times at which the significant changes in \( V_{\max 50} \) and \( V_{\max 25} \) occurred.

Statistical analyses were not performed on FVC, \( FEV_1 \), \( FEV_1/FVC \), and PEFR if the mean percent changes in these parameters were less than ten percent. If one of the subgroups had a mean change of greater than ten percent for any specific time (5, 15 or 45 minutes after drainage), a standard T-test (Walker and Lev 1953: 153) was done to determine if the change was significant.
CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

Characteristics of the Sample

The sample consisted of 19 patients; 9 had cystic fibrosis, and 10 had chronic bronchitis. The subjects were referred to in terms of three groups: (1) the combined group including all subjects, (2) the cystic fibrosis subgroup including all subjects with the diagnosis of cystic fibrosis, and (3) the chronic bronchitic subgroup including all subjects with the diagnosis of chronic bronchitis.

Subjects in the cystic fibrosis subgroup, 8 females and 1 male, ranged in age from 9 to 36 years, with a mean age of 17 years. Antibiotics were being taken by 3 of the 9 patients. No subjects in this subgroup were taking bronchodilators. Based on normal pulmonary function values set forth by Polgar and Promadhat (1971: 180, 100) for children and Bates et al. (1971: 93-94) for adults, the baseline percent predicted FVC ranged from 39 percent to 163 percent with a mean of 80 percent; and the baseline percent predicted FEV₁ ranged from 25 percent to 127 percent with a mean of 57 percent. The baseline FEV₁/FVC ratio ranged from 51 percent to 72 percent, with a mean of 59 percent.
The cystic fibrosis patients were given a clinical score based on the National Institute of Health's Scoring System for cystic fibrosis as developed by Taussig et al. (1973). A score of 100 indicated normalcy with decreasing scores indicating increasing clinical severity of disease. The scores ranged from 88 to 51, with a mean score of 73, corresponding to a range in clinical severity from mild to severe (see Table 1).

The subjects in the chronic bronchitic subgroup, 3 females and 7 males, ranged in age from 58 to 70 years, with a mean age of 61 years. Three of the 10 subjects were taking antibiotics for pulmonary infection and 9 were taking bronchodilators. All of the subjects with chronic bronchitis also had the diagnosis of chronic obstructive lung disease on their medical record. Based on spirometric measurements done before and after the inhalation of bronchodilators, 9 of the 10 subjects had evidence of a reversible component of their airways obstruction. Three of the 10 subjects also had the specific diagnosis of emphysema on their medical record. Based on normal values set forth by Bates et al. (1971: 93-94), the baseline percent predicted FVC ranged from 50 to 96 percent with a mean of 71 percent, and the baseline percent predicted FEV₁ ranged from 19 to 84 percent with a mean of 41 percent. The baseline FEV₁/FVC ratio ranged from 19 percent to 71 percent with a mean of 40 percent (see Table 2).
Table 1. Characteristics of the Subjects in the Cystic Fibrosis Subgroup

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Sex</th>
<th>Height (cm)</th>
<th>Baseline FVC (% Predicted)</th>
<th>Baseline FEV₁ (% Predicted)</th>
<th>Baseline FEV₁/FVC (%)</th>
<th>On Antibiotics</th>
<th>Clinical Score</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>11</td>
<td>Female</td>
<td>114</td>
<td>52</td>
<td>33</td>
<td>60</td>
<td>No</td>
<td>66</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>Female</td>
<td>135</td>
<td>61</td>
<td>35</td>
<td>54</td>
<td>Yes</td>
<td>51</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>Female</td>
<td>175</td>
<td>97</td>
<td>79</td>
<td>66</td>
<td>No</td>
<td>Not Done</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>Male</td>
<td>128</td>
<td>39</td>
<td>25</td>
<td>55</td>
<td>Yes</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Female</td>
<td>138</td>
<td>84</td>
<td>58</td>
<td>63</td>
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<td>88</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>Female</td>
<td>173</td>
<td>89</td>
<td>66</td>
<td>54</td>
<td>No</td>
<td>88</td>
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<tr>
<td>7</td>
<td>16</td>
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<td>166</td>
<td>69</td>
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<td>81</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
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<td>163</td>
<td>127</td>
<td>72</td>
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<td>74</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>Female</td>
<td>157</td>
<td>69</td>
<td>40</td>
<td>51</td>
<td>No</td>
<td>Not Done</td>
</tr>
<tr>
<td>Subject</td>
<td>Age</td>
<td>Sex</td>
<td>Height (cm)</td>
<td>FVC (% Predicted)</td>
<td>FEV₁ (% Predicted)</td>
<td>FEV₁/FVC (%)</td>
<td>On Antibiotics</td>
<td>On Oral Bronchodilators</td>
</tr>
<tr>
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<td>-----</td>
<td>------</td>
<td>-------------</td>
<td>------------------</td>
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<tr>
<td>2</td>
<td>63</td>
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<td>180</td>
<td>70</td>
<td>66</td>
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<tr>
<td>3</td>
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<td>160</td>
<td>54</td>
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</tr>
<tr>
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<td>172</td>
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<td>32</td>
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<tr>
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<td>63</td>
<td>Male</td>
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<td>50</td>
<td>42</td>
<td>63</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>61</td>
<td>Male</td>
<td>179</td>
<td>73</td>
<td>19</td>
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<td>96</td>
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<td>No</td>
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<td>69</td>
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<td>25</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
<td>Female</td>
<td>152</td>
<td>68</td>
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<td>Yes</td>
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<tr>
<td>10</td>
<td>63</td>
<td>Male</td>
<td>174</td>
<td>92</td>
<td>84</td>
<td>50</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Analysis of the MEFV Curves

Three flow volume curves were taken at each of the following times: before drainage, and at 5, 15 and 45 minutes after drainage. Of the three curves taken, the curve with the largest FVC was used for analysis. If more than one curve had the same FVC, the curve with the best flow rates was utilized.

The following measurements were calculated from each curve: (1) PEFR, (2) FEV₁, (3) FVC, and (4) FEV₁/FVC ratio. In addition, Vmax 50 and Vmax 25 were calculated from the predrainage MEFV curves. On the postdrainage curves, isovolume flow rates were calculated in the following manner: (1) on the predrainage MEFV curves measurements were made of the volume down from total lung capacity [TLC] to 50 percent (volume₁) and 25 percent (volume₂) of the baseline FVC; volume₁ and volume₂ were the points at which Vmax 50 and Vmax 25 were measured; (2) on the postdrainage curves, the same volumes (volume₁ and volume₂) were subtracted from TLC and were then considered to be the isovolume points; (3) flow rates were then measured at these volume points and reported as the isovolume flow rate near 50 percent FVC and the isovolume flow rate near 25 percent FVC. Thus assuming that TLC remained constant flow rates at or near 25 percent FVC and at or near 50 percent FVC were always measured at the same absolute
lungs volume down from TLC on all curves. Figure 4 illustrates how the measurements described above were calculated from the MEFV curves.

Postdrainage isovolumes near 25 percent and 50 percent FVC were similar to the actual postdrainage 25 percent and 50 percent FVC points (see Table 3).

Table 3. Actual Postdrainage Lung Volumes Where Isovolume Flow Rates Near 50 Percent and 25 Percent FVC Were Measured

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>Actual Postdrainage Lung Volumes Where Isovolume Flow Rates Near 50% FVC Were Measured</th>
<th>Actual Postdrainage Lung Volumes Where Isovolume Flow Rates Near 25% FVC Were Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Range (%FVC)</td>
<td>39-61</td>
<td>9-42</td>
</tr>
<tr>
<td>Mean (%FVC)</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>51</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td>29</td>
</tr>
</tbody>
</table>

The combined errors inherent in the test procedure and calculated measurements were estimated to total 10 percent. Therefore, a measurement was considered to show significant change only if the percent change was greater than 10 percent.
Fig. 4. Calculation of Isovolume Flow Rates From the MEFV Curve

1 = Baseline Curve (Pre-drainage)
2 = Post-drainage Curve

1 = Baseline Curve (Pre-drainage)
2 = Post-drainage Curve

Isovolume flow near 50% FVC

Isovolume Flow near 25% FVC

$V_{\text{max}}$

$V_{\text{max}}$

(50% Baseline FVC)

(25% Baseline FVC)
FVC, FEV₁, and FEV₁/FVC Ratio

Table 4 presents the number of subjects in whom the FEV₁, FVC, and FEV₁/FVC ratio decreased, increased, and remained the same at 5, 15, and 45 minutes after postural drainage.

Table 4. Number of Subjects Who Demonstrated an Increase, Decrease, and No Change for FVC, FEV₁, and FEV₁/FVC Ratio at Each Time for Each Group

<table>
<thead>
<tr>
<th>Time After Postural Drainage</th>
<th>Group</th>
<th>FVC</th>
<th>FEV₁</th>
<th>FEV₁/FVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I¹</td>
<td>D</td>
<td>O</td>
</tr>
<tr>
<td>5 minutes</td>
<td>CF</td>
<td>3</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
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<td>5</td>
<td>8</td>
</tr>
<tr>
<td>15 minutes</td>
<td>CF</td>
<td>2</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>45 minutes</td>
<td>CF</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>4</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

*¹I = Increase
D = Decrease
O = No Change
CF = Cystic Fibrosis Subgroup
CB = Chronic Bronchitic Subgroup

The FVC, FEV₁, and FEV₁/FVC ratio remained the same in most of the subjects at 5, 15, and 45 minutes after drainage.
Table 5 presents the mean percent changes from baseline for FVC, FEV₁, and FEV₁/FVC ratio at 5, 15, and 45 minutes after drainage. In the combined group, the mean percent changes in these parameters were always less than 7 percent at 5, 15, and 45 minutes after drainage.

It was hypothesized that in the combined group at 5 minutes after postural drainage there would be no significant improvement in the FVC, FEV₁, and FEV₁/FVC ratio, but that by 15 and 45 minutes after drainage there would be a significant increase in these parameters when compared to the pretreatment control values. Statistical analyses were not performed on the mean percent changes in these parameters because the changes were within the 10 percent error assumed for these tests. The hypothesis, that in the combined group there would be a significant change in the FEV₁, FVC, and FEV₁/FVC ratio at 5 minutes after drainage, was rejected. The null hypothesis that in the combined group there would be no significant increase in these parameters at 15 and 45 minutes after postural drainage was accepted.

PEFR

Changes in PEFR were distinct for the two subgroups. Table 6 presents the number of subjects in whom the PEFR increased, decreased, and remained the same at 5, 15, and 45 minutes after drainage. The percent changes from baseline
Table 5. Mean Percent Change From Baseline for FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC Ratio At Each Time For Each Group

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>FEV&lt;sub&gt;1&lt;/sub&gt; Mean % Change (Range)</th>
<th>FVC Mean % Change (Range)</th>
<th>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC Mean % Change (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CF +6 (-4 - +15)</td>
<td>+5 (-8 - +22)</td>
<td>0 (-7 - +5)</td>
</tr>
<tr>
<td></td>
<td>CB +4 (-13 - +39)</td>
<td>-2 (-18 - +28)</td>
<td>+2 (-13 - +22)</td>
</tr>
<tr>
<td></td>
<td>Combined +5 (-13 - +39)</td>
<td>+1 (-18 - +28)</td>
<td>+1 (-13 - +32)</td>
</tr>
<tr>
<td>15</td>
<td>CF +5 (-9 - +17)</td>
<td>+5 (-9 - +15)</td>
<td>0 (-5 - +3)</td>
</tr>
<tr>
<td></td>
<td>CB -4 (-45 - +15)</td>
<td>+4 (-15 - +30)</td>
<td>-5 (-41 - +6)</td>
</tr>
<tr>
<td></td>
<td>Combined -1 (-45 - +17)</td>
<td>+4 (-15 - +30)</td>
<td>-2 (-41 - +6)</td>
</tr>
<tr>
<td>45</td>
<td>CF +9 (-4 - +25)</td>
<td>+6 (-2 - +20)</td>
<td>+1 (-7 - +6)</td>
</tr>
<tr>
<td></td>
<td>CB +1 (-45 - +38)</td>
<td>+7 (-10 - +19)</td>
<td>-4 (-38 - +7)</td>
</tr>
<tr>
<td></td>
<td>Combined +4 (-45 - +38)</td>
<td>+6 (-10 - +20)</td>
<td>-1 (-38 - +7)</td>
</tr>
</tbody>
</table>

CF = Cystic Fibrosis Subgroup
CB = Chronic Bronchitic Subgroup
PEFR at 5, 15, and 45 minutes after drainage are presented in Table 7.

Table 6. Number of Subjects Who Demonstrated an Increase, Decrease, and No Change for PEFR at Each Time for Each Group

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>Group</th>
<th>I</th>
<th>D</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CF</td>
<td>1</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>0</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>1</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>CF</td>
<td>2</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>4</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>45</td>
<td>CF</td>
<td>4</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>8</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

I = Increase  
D = Decrease  
O = No Change  
CF = Cystic Fibrosis Subgroup  
CB = Chronic Bronchitic Subgroup
Table 7. Mean Percent Change From Baseline for PEFR at Each Time for Each Group

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>Group</th>
<th>PEFR Mean Percent Change (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CF</td>
<td>-3 (-12 - +17)</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>-15 (-33 - 0)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>-9 (-33 - +17)</td>
</tr>
<tr>
<td>15</td>
<td>CF</td>
<td>+2 (-9 - +32)</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>-6 (-44 - +27)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>-2 (-44 - +32)</td>
</tr>
<tr>
<td>45</td>
<td>CF</td>
<td>+16 (-4 - +44)</td>
</tr>
<tr>
<td></td>
<td>CB</td>
<td>-1 (-30 - +30)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>+7 (-30 - +44)</td>
</tr>
</tbody>
</table>

CF = Cystic Fibrosis Subgroup
CB = Chronic Bronchitic Subgroup
In the combined group at 5 minutes after postural drainage, the PEFR in 1 subject increased, in 8 subjects decreased, and in 10 subjects remained the same (see Table 6). The mean percent change was -9 percent with a range of -33 percent to +17 percent (see Table 7). It was hypothesized that in the combined group at 5 minutes after postural drainage there would be no significant change in PEFR. The hypothesis was accepted for the combined group because the mean percent change was within the 10 percent error assumed for the test. The percent change in PEFR was then examined separately in each subgroup. In the chronic bronchitic subgroup the PEFR decreased in 6 subjects, remained the same in 4 and increased in none. In the cystic fibrosis subgroup the PEFR decreased in 2 subjects, remained the same in 6, and increased in 1. The cystic fibrosis subgroup had a mean percent change of -3 percent with a range of -12 percent to +17 percent and the chronic bronchitic subgroup had a mean percent change of -15 percent with a range of -33 percent to 0 percent. Since the cystic fibrosis subgroup had a mean percent change that was within the error assumed for the test, the hypothesis that there would be no significant change in PEFR at 5 minutes after postural drainage was accepted for this subgroup. The percent changes in the chronic bronchitic subgroup at 5 minutes after drainage were examined by a standard T-test
for differences. There was a significant difference at the .01 level. Therefore the hypothesis that there would be a significant change in PEFR at 5 minutes after postural drainage in the chronic bronchitic subgroup was accepted.

It was hypothesized that at 15 minutes after drainage there would be a significant increase in PEFR. This hypothesis was rejected for the chronic bronchitic subgroup, the cystic fibrosis subgroup, and the combined group because the mean percent changes for each at 15 minutes after drainage were within the 10 percent error assumed for the test (see Table 7).

In the combined group, the PEFR decreased in 3 subjects, remained the same in 3 and increased in 8. The mean percent change was +7 percent with a range of -30 percent to +44 percent. In the chronic bronchitic subgroup, the PEFR was decreased in 3 subjects, remained the same in 3, and increased in 4. The mean percent change was -1 percent with a range of -30 percent to +30 percent. It was hypothesized that at 45 minutes after drainage there would be a significant increase in PEFR. This hypothesis was rejected for the combined group and the chronic bronchitic subgroup because the mean percent changes in PEFR for each at 45 minutes after drainage were within the 10 percent error assumed for the tests.
In the cystic fibrosis subgroup at 45 minutes after drainage the PEFR decreased in no subjects, remained the same in 5 and increased in 4. The mean percent change was +16 percent with a range of -4 percent to +44 percent. The mean percent changes in the cystic fibrosis subgroup at 45 minutes after drainage were subjected to a standard T-test for differences. There was a significant difference at the 0.01 level. Therefore, the hypothesis that there would be a significant increase in PEFR at 45 minutes after postural drainage was accepted for the cystic fibrosis subgroup.

<table>
<thead>
<tr>
<th>Isovolume Flow Rates Near 50 Percent FVC and Near 25 Percent FVC</th>
</tr>
</thead>
</table>

The number of subjects in whom the isovolume flow rates near 50 percent and 25 percent FVC increased, decreased, and remained the same at 5, 15 and 45 minutes after drainage is presented in Table 8. The mean percent changes at 5, 15, and 45 minutes after drainage for isovolume flow rates near 50 percent and 25 percent FVC, as compared to predrainage Vmax 50 and Vmax 25 respectively, are presented in Table 9.

It was hypothesized that the cystic fibrosis subgroup would demonstrate a significantly greater improvement in their isovolume flows at 5, 15, and 45 minutes after postural drainage than would the chronic bronchitic
Table 8. Number of Subjects Who Demonstrated an Increase, Decrease, and No Change For Isovolume Flow Rates Near 50 Percent and 25 Percent FVC at Each Time For Each Group

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>Isovolume Flow Rates Near 50% FVC</th>
<th>Isovolume Flow Rates Near 25% FVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>D</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>CB</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Combined</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>CB</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Combined</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>CB</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Combined</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

I = Increase
D = Decrease
0 = No Change

CF = Cystic Fibrosis Subgroup
CB = Chronic Bronchitic Subgroup
Table 9: Mean Percent Change From Baseline For Isovolume Flow Rates Near 50 Percent and 25 Percent FVC at Each Time For Each Group

<table>
<thead>
<tr>
<th>Minutes After Postural Drainage</th>
<th>Isovolume Flow Rates Near 50% FVC</th>
<th>Isovolume Flow Rates Near 25% FVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean % Change (Range)</td>
<td>Mean % Change (Range)</td>
</tr>
<tr>
<td>5 CF = Cystic Fibrosis Subgroup</td>
<td>5 CF = Cystic Fibrosis Subgroup</td>
<td>5 CF = Cystic Fibrosis Subgroup</td>
</tr>
<tr>
<td>15 CB = Chronic Bronchitic Subgroup</td>
<td>15 CB = Chronic Bronchitic Subgroup</td>
<td>15 CB = Chronic Bronchitic Subgroup</td>
</tr>
<tr>
<td>45 Combined = Combined</td>
<td>45 Combined = Combined</td>
<td>45 Combined = Combined</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean % Change (Range)</th>
<th>Mean % Change (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>-7 (-50 - +22)</td>
<td>+18 (-33 - +25)</td>
</tr>
<tr>
<td>GB</td>
<td>-9 (-38 - +20)</td>
<td>+6 (-20 - +100)</td>
</tr>
<tr>
<td>Combined</td>
<td>-8 (-50 - +22)</td>
<td>+12 (-33 - +100)</td>
</tr>
<tr>
<td>CF</td>
<td>+11 (-22 - +40)</td>
<td>+44 (0 - +100)</td>
</tr>
<tr>
<td>GB</td>
<td>+2 (-60 - +58)</td>
<td>+24 (-30 - +100)</td>
</tr>
<tr>
<td>Combined</td>
<td>+7 (-60 - +58)</td>
<td>+33 (-30 - +100)</td>
</tr>
<tr>
<td>CF</td>
<td>+21 (-20 - +50)</td>
<td>+63 (+6 - +150)</td>
</tr>
<tr>
<td>GB</td>
<td>+7 (-25 - +36)</td>
<td>+45 (-10 - +100)</td>
</tr>
<tr>
<td>Combined</td>
<td>+13 (-25 - +50)</td>
<td>+54 (-10 - +150)</td>
</tr>
</tbody>
</table>
subgroup. By means of a T-test, the mean percent change in isovolume flow near 25 percent FVC in the cystic fibrosis subgroup was compared to the mean percent change in the isovolume flow near 25 percent FVC in the chronic bronchitic subgroup at 5, 15 and 45 minutes after drainage. The T-test was also used to compare the mean percent changes in isovolume flows near 50 percent FVC in the two subgroups, at 5, 15, and 45 minutes after drainage. None of the T values were significant and the above hypotheses were rejected. The null hypothesis, that at 5, 15, and 45 minutes after drainage there would be no significant difference between the degree of improvement in the cystic fibrosis subgroup's isovolume flows and the chronic bronchitic subgroup's isovolume flows near both 25 percent and 50 percent FVC was accepted.

Since there was no significant difference between the two subgroups in regard to percent change in isovolume flows at 5, 15, and 45 minutes after drainage, analyses of variance were done on the combined group. Analysis of variance was performed on the percent change in isovolume flow with time near 50 percent FVC while a separate analysis was performed on the percent change in isovolume flow with time near 25 percent FVC. Both analyses of variance were significant at the 0.05 level, thus demonstrating that in the combined group there was a significant
increase in isovolume flows near 25 percent and 50 percent FVC with time. The remainder of the data on isovolume flow will be discussed solely in reference to the combined group and presents the results of T-tests done to determine the times at which the significant changes in isovolume flows occurred.

At five minutes after postural drainage, isovolume flow near 50 percent FVC increased in 5 subjects, decreased in 10 subjects and stayed the same in 4 subjects. The 5 minute mean percent change in isovolume flow near 50 percent FVC was -8 percent with a range of -50 percent to +25 percent. It was hypothesized that at 5 minutes after drainage there would be no significant change in isovolume flow near 50 percent and 25 percent FVC. Since this percent change was within the 10 percent error assumed for the test, the null hypothesis that there would be no significant change in isovolume flow near 50 percent FVC was accepted. The 5 minute mean percent change in isovolume flow near 25 percent FVC was +12 percent with a range of -33 percent to +100 percent. At 5 minutes after postural drainage, isovolume flow near 25 percent FVC increased in 7 subjects, decreased in 5 subjects and remained the same in 7 subjects. A T-test for differences demonstrated the percent change to be significant at the 0.05 level. The alternate hypothesis, that at 5 minutes after
drainage there would be a significant increase in isovolume flow near 25 percent FVC was accepted.

It was hypothesized that at 15 minutes after drainage there would be a significant increase in isovolume flow near 50 percent and 25 percent FVC. The 15-minute mean percent change in isovolume flow near 50 percent FVC was +7 percent with a range of -60 percent to +58 percent. At 15 minutes after drainage the isovolume flow near 50 percent FVC had increased in 7 subjects, decreased in 4, and remained the same in 8. A T-test for differences demonstrated the percent change was not significant. Therefore, the hypothesis that at 15 minutes after postural drainage there would be a significant increase in isovolume flow near 50 percent FVC, was rejected. The null hypothesis, that at 15 minutes after drainage there would be no significant change in isovolume flows near 50 percent FVC was accepted. The 15-minute mean percent change in isovolume flow near 25 percent FVC was +33 percent with a range of -30 percent to +100 percent. The 15-minute isovolume flow rate near 25 percent FVC increased in 12 subjects, decreased in 2, and remained the same in 5. A T-test for differences showed the percent change to be significant at the 0.01 level. Therefore, the hypothesis that at 15 minutes after postural drainage there would be a significant increase in isovolume flows near 25 percent FVC, was accepted.
It was hypothesized that at 45 minutes after postural drainage there would be a significant increase in isovolume flow near 50 percent and 25 percent FVC. The 45-minute mean percent change in isovolume flow near 50 percent FVC was plus 13 percent with a range of -25 percent to +50 percent. This parameter increased in 11 subjects, decreased in 5 subjects, and stayed the same in 3. A T-test for differences showed the percent change to be significant at the 0.025 level. Therefore, the hypothesis that at 45 minutes after postural drainage there would be a significant increase in isovolume flow near 50 percent FVC was accepted. The 45-minute mean percent change in isovolume flow near 25 percent FVC was +54 percent with a range of -10 percent to +150 percent. At 45 minutes after drainage this parameter increased in 15 subjects, decreased in none, and remained the same in 4. A T-test for differences showed the percent change to be significant at the 0.001 level. Therefore, the hypothesis that there would be a significant increase in isovolume flow near 25 percent FVC, was accepted.

Other Variables

There was no correlation between the amount of sputum produced and the change in isovolume flow near 25 percent FVC at 45 minutes after postural drainage. The sputum volume produced during the postural drainage
procedure and the 45 minutes after the procedure ranged from 5 to 70 cubic centimeters, with a mean of 15 cubic centimeters. Mucopurulent sputum was produced by 17 subjects and mucoid sputum was produced by 2 subjects, both of whom had the diagnosis of chronic bronchitis.

Although none of the subjects had taken inhaled bronchodilators for at least 4 hours before postural drainage, 9 of the 19 were taking oral bronchodilators on a regular basis; the oral bronchodilators were not discontinued for the study. In those subjects who were taking oral bronchodilators the mean percent change in isovolume flow near 25 percent FVC at 45 minutes after drainage was +48 percent with a range of -10 percent to +120 percent; in those subjects who were not taking oral bronchodilators it was +61 percent with a range of +6 percent to +150 percent. Therefore it is doubtful that oral bronchodilator therapy had a significant effect on isovolume flow rates near 25 percent FVC at 45 minutes after drainage.

During and for some time after the postural drainage procedure, 6 of the 19 subjects had audible wheezes (wheezing was heard without the use of a stethoscope). In subjects who had audible wheezes the mean percent change in isovolume flow near 25 percent FVC at 45 minutes after drainage was +27 percent with a range of -10 percent to +100 percent; in those subjects in whom no wheezing was
heard the mean change was +66 percent with a range of +6 percent to +150 percent. A T-test for differences between the group means was significant at the 0.05 level, suggesting that wheezing may have had an effect on isovolume flow rates near 25 percent FVC at 45 minutes after drainage.

**Summary**

In summary, the following changes from predrainage flow volume measurements were noted as being significant.

1. At 5 minutes after drainage the chronic bronchitic subgroup had a significant decrease in PEFR (p less than 0.01).
2. At 45 minutes after drainage the cystic fibrosis subgroup had a significant increase in PEFR (p less than 0.01).
3. In the combined group there was a significant increase with time in isovolume flows near 50 percent and 25 percent FVC (p less than 0.05).
4. At 5 minutes after drainage the combined group had a significant increase in isovolume flow near 25 percent FVC (p less than 0.05).
5. At 15 minutes after drainage the combined group had a significant increase in isovolume flow near 25 percent FVC (p less than 0.01).
6. At 45 minutes after drainage the combined group had a significant increase in isovolume flow near 50 percent FVC (p less than 0.025).

7. At 45 minutes after drainage the combined group had a significant increase in isovolume flow near 25 percent FVC (p less than 0.001).
CHAPTER 5

DISCUSSION AND CONCLUSIONS

The discussion will (1) compare the results with those of similar studies; (2) interpret the results in terms of pulmonary physiology; (3) focus on how, through an increased understanding of the effects of postural drainage on airflow, health professionals can more rationally prescribe postural drainage for patients with cystic fibrosis or chronic bronchitis; and (4) present recommendations for further study on postural drainage.

FVC

There was no significant change in FVC at 5, 15, and 45 minutes after postural drainage, although at 45 minutes after drainage there was a trend toward an increase. The 45-minute mean percent change in FVC was +6 percent in the cystic fibrosis subgroup, +7 percent in the chronic bronchitic subgroup, and +6 percent in the combined group. Similar findings have been reported by other investigators. March (1971) reported no significant change in FVC at 30 minutes after postural drainage (done without percussion and vibration) in 37 subjects with chronic obstructive pulmonary disease. The mean FVC was 1.69 liters both before and at 30 minutes after drainage. Peterson et al.
(1967) measured FVC before and after 10 daily postural drainage treatments in 10 patients with acute exacerbations in chronic bronchitis. Postural drainage was the only form of therapy prescribed outside of potassium chloride and calcium lactate. The FVC at 10 days was unchanged from the control values in 7 of the 10 subjects, decreased in 1 and increased in 2. Although the present study only evaluated the response to one treatment, the data at 45 minutes after drainage in which FVC remained the same in 6 of the 10 chronic bronchitic subjects, increased in 3, and decreased in 1, demonstrate similar results to Peterson et al. (1967) and March (1971).

Motoyama (1973) reported a significant increase in FVC at 45 minutes after postural drainage in 10 cystic fibrosis patients. The significance level was not given, but there was an approximate change of +10 percent. Tecklin and Holsclaw (1975) reported a statistically significant increase (p less than .005) in FVC at 5 minutes after postural drainage in 26 patients with cystic fibrosis, although the mean change in FVC was only +4 percent. By definition in the present study this degree of change in FVC would have been considered nonsignificant.

Although some of the findings demonstrated a small trend toward an increase in FVC after postural drainage, the significance of these trends is questionable.
due to the degree of error inherent in the test and due to the lack of agreement as to what percent change in FVC is significant. The FVC, therefore, appears to be of limited value in measuring significant changes in lung function after postural drainage.

**FEV₁ and PEFR**

In the present study there was no significant change in FEV₁ at 5, 15, and 45 minutes after postural drainage. At 45 minutes after drainage the mean percent change in FEV₁ was +9 percent in the cystic fibrosis subgroup, +1 percent in the chronic bronchitic subgroup, and +4 percent in the combined group. Similar findings have been reported by other investigators. March (1971) also reported no significant change in FEV₁ at 30 minutes after postural drainage in 37 patients with chronic obstructive pulmonary disease. Likewise, Tecklin and Holsclaw (1975) reported no significant change in FEV₁ at 5 minutes after postural drainage in 29 subjects with cystic fibrosis. The 5-minute mean percent change in FEV₁ was +3 percent.

Kang et al. (1974) reported that FEV₁ increased by more than 15 percent after one session of postural drainage in 8 of 15 subjects with obstructive lung disease and remained the same in 7. The mean percent change and its significance level were not given. Huber et al.
(1974) reported a mean percent change in FEV\textsubscript{1} of +11 percent at 30 minutes after one session of postural drainage in 11 asthmatic children.

In the present study the only significant changes in PEFR were a decrease at 5 minutes after drainage in the chronic bronchitic subgroup, and an increase at 45 minutes in the cystic fibrosis subgroup. Motoyama (1973) also reported a significant increase in PEFR at 45 minutes after postural drainage in 10 cystic fibrosis patients. The mean percent change was approximately +10 percent, compared to +16 percent in the present study. Likewise, Tecklin and Holsclaw (1975) reported a statistically significant increase (p less than .0005) in PEFR. The mean change was +6 percent at 5 minutes after postural drainage in 26 subjects with cystic fibrosis. Peterson et al. (1967) measured PEFR before and after 10 daily postural drainage treatments in 10 subjects with acute exacerbation in chronic bronchitis. The PEFR at 10 days was unchanged from the control values in 4 of the 10 subjects, increased in 6 and decreased in none. Although the present study only evaluated the response to one treatment, the data at 45 minutes after drainage in which PEFR increased in 4 of 10 chronic bronchitic subjects, decreased in 3 and remained the same in 3, demonstrated similar results to Peterson et al. (1967). From the above
data there appears to be a small trend toward an increase in PEFR after postural drainage in selected patients with cystic fibrosis, although the significance of this trend is uncertain.

Greater discrimination in the selection and description of subjects may result in a subpopulation where the FEV₁ and PEFR consistently show improvement after postural drainage. With the present state of knowledge PEFR and FEV₁ alone should not be used to determine who benefits from postural drainage since it may result in the elimination of a form of therapy which would benefit lung function along other parameters.

| Isovolume Flow Rates Near 50 Percent FVC and Near 25 Percent FVC |

In the combined group, there was a statistically significant (p less than 0.05) increase with time in isovolume flow rates near 25 percent and 50 percent FVC so that by 45 minutes after postural drainage there was a statistically significant increase in isovolume flow near 50 percent FVC (p less than 0.025) and near 25 percent FVC (p less than 0.001). The improvement in flow rates at low lung volumes reflects a decrease in airways resistance in small peripheral airways (Motoyama 1973: 336). The data, therefore, support the theory that postural drainage clears secretions from small peripheral airways,
thus increasing their calibre and decreasing their resistance to airflow.

These findings are consistent with those of Motoyama (1973) who also found a statistically significant increase in $\dot{V}_{\text{max}} 25$ and $\dot{V}_{\text{max}} 50$ at 45 minutes after postural drainage in 10 subjects with cystic fibrosis. At 45 minutes after drainage he reported a mean change in $\dot{V}_{\text{max}} 50$ of approximately +30 percent and a mean change in $\dot{V}_{\text{max}} 25$ of about +58 percent. These data correspond to the present study in which the cystic fibrosis subgroup at 45 minutes after drainage demonstrated a mean change in isovolume flow near 50 percent FVC of +21 percent and a mean change in isovolume flow near 25 percent FVC of +63 percent.

In the present study at 5 minutes after postural drainage the combined group demonstrated a trend toward a decrease in isovolume flow rates at 50 percent FVC (mean change -8 percent), while at the same time demonstrating a statistically significant increase in isovolume flow near 25 percent FVC (mean change +12 percent). The findings can be interpreted on the basis of larger airways obstruction by sputum being mobilized from small peripheral airways into larger central airways. The continual improvement with time in isovolume flow rates near 25 percent and 50 percent FVC can be attributed to further coughing and expectoration of mobilized sputum.
The findings of other investigators compare well with the present study in terms of the changes in isovolume flow rates at 5 minutes after drainage. Although the 10 cystic fibrosis subjects in Motoyama's (1973) study demonstrated a significant increase (mean change +60 percent compared to a mean change in the present study's cystic fibrosis subgroup of -7 percent) in $V_{\text{max}}$ at 5 minutes after drainage; the investigator pointed out that some individuals demonstrated an initial decrease in $V_{\text{max}}$ which improved after further expectoration. Tecklin and Holsclaw (1975) reported a nonsignificant decrease (mean change -3 percent) in maximal mid-expiratory flow rate [MMEFR] at 5 minutes after drainage in 26 subjects with cystic fibrosis. Since the MMEFR gives an average flow rate over the mid 50 percent of the FVC, these results are compatible with the present study in which the cystic fibrosis subgroup at 5 minutes after drainage also demonstrated a nonsignificant decrease (mean change -7 percent) in isovolume flow near 50 percent FVC. It is possible that if Tecklin and Holsclaw (1975) had tested their subjects at 30 or 45 minutes after drainage they would have demonstrated an increase in MMEFR due to further expectoration of mobilized sputum.
Physiological Interpretations

Several theories can be proposed in an attempt to explain why flow rates significantly improved at low lung volumes and demonstrated little change at higher lung volumes. One factor may have been that many of the subjects appeared short of breath and fatigued immediately after the drainage procedure, making it more difficult for them to perform a forced vital capacity maneuver. Since flow rates at high lung volumes (PEFR and FEV₁) are effort-dependent, they can be diminished in the presence of postdrainage fatigue. Another factor leading to the variable and insignificant changes in PEFR and FEV₁ might have been the movement of secretions from small peripheral airways into large central airways during the drainage procedure. As the sputum was mobilized there was a decrease in resistance in small airways and an increase in resistance in the large airways, thereby resulting in an increase in flow rates at low lung volumes (Vmax 25 and Vmax 50) and a decrease or little change in flow rates at high lung volumes (PEFR and FEV₁). Thus, changes in flow rates at low lung volumes (Vmax 25 and Vmax 50) may be a more sensitive indicator of improvements in lung function after postural drainage than are changes in flow rates at higher lung volume.
Other Variables

In this investigation there was no correlation between the volume of sputum produced and the mean percent change in isovolume flow near 25 percent FVC. Other investigators also demonstrated that the sputum volume expectorated was not a valid reflection of the effects of postural drainage on lung function (Anthonisen et al. 1964, March 1971, Peterson et al. 1967).

This investigator along with others (Huber et al. 1974, Tecklin and Holsclaw 1975) observed wheezing during the postural drainage procedure. From these studies it is not clear what specific effect wheezing has on the efficacy of postural drainage in improving flow rates.

Clinical Implications

A basic question is how the health professional can more objectively evaluate and more rationally prescribe postural drainage to patients with cystic fibrosis or chronic bronchitis? As noted earlier, there was a significant decrease in PEFR in the cystic fibrosis subgroup at 5 minutes after postural drainage. At that time many of the patients in the chronic bronchitic subgroup were also observed to be having signs of wheezing, fatigue, and shortness of breath. Tiredness and shortness of breath probably occurred as a result of the energy used in positioning and coughing and because of the increased work of
breathing as a result of wheezing. Nurses and physicians must be aware of the fact that shortness of breath may initially mask the beneficial effects of postural drainage. They may be able to minimize these untoward effects by administering pharmacologic agents promoting bronchodilation before postural drainage and by allowing the patient to have rest periods between the various positions used during the drainage procedure. It is also important to plan for a period of rest for 30 to 60 minutes after drainage during which time the patient must be encouraged to cough and expectorate the mobilized sputum.

The improvements in isovolume flow rates near 50 percent and near 25 percent FVC clearly demonstrated that in the cystic fibrosis subgroup and the chronic bronchitic subgroup postural drainage was effective in mobilizing sputum away from the small peripheral airways, thus allowing for a decrease in frictional resistance to airflow. Nurses and physicians should therefore continue to incorporate this form of therapy in the care of patients with cystic fibrosis or chronic bronchitis. It must be kept in mind that the beneficial effects may be difficult to evaluate clinically, especially immediately after just one session of postural drainage. The sputum volume produced and the patient's acute subjective impressions of his ability to breathe more easily after postural drainage
may not always positively correlate with the degree of improvement in airflow, which may be more long lasting.

**Suggestions for Further Study**

One drawback to the present study is the fact that the chronic bronchitis patients were a very select group because the investigator utilized subjects whose primary and major disease process was chronic bronchitis with obvious mucus production. Frequently, however, patients with obstructive lung disease have a primary diagnosis of asthma, emphysema, or bronchiectasis with chronic bronchitis being an associated problem rather than the major cause of their pulmonary dysfunction. Similar research needs to be done on subjects presenting the full range of obstructive lung disease in order to ascertain if there are differences between subgroups.

From this study it could not be determined how long the beneficial airflow effects of postural drainage were maintained. Further studies should measure MEFV curves three to four hours after drainage or until such time as flow rates would begin to fall to predrainage levels. From such data it could be determined how frequently postural drainage should be prescribed.

Since many of the subjects demonstrated wheezing in response to postural drainage, a study should be designed in which the combined effects of bronchodilators
and postural drainage, in contrast to either alone, would be evaluated. Criteria for evaluation would include flow measurements as well as clinical symptomatology such as fatigue, shortness of breath, and wheezing.

Another drawback to this study is inherent in the measurement tool itself, the flow-volume curve, because it involves the performance of numerous forced vital capacity maneuvers. These maneuvers tend to cause mobilization of sputum, wheezing and coughing. It is possible that by performing a number of forced vital capacity maneuvers one could effectively clear as much sputum as with postural drainage. To test for this a study should be done in which MEFV curves would be measured before, 5 minutes after, 15 minutes after, and 45 minutes after a 30-minute session which would involve the performance of one forced vital capacity maneuver every five minutes times six. Each maneuver would be followed by an attempt to cough and expectorate sputum.
CHAPTER 6

SUMMARY

Postural drainage is an important nursing procedure in the care of patients with cystic fibrosis or chronic bronchitis. It provides gravitational and mechanical forces that are thought to augment the natural pulmonary clearance mechanisms (cough transport and mucociliary transport), thereby clearing the airways of excessive sputum. Postural drainage with percussion and vibration has been suggested as a method to provide for the mobilization of secretions from small peripheral airways into larger proximal airways so that cough transport can then clear the large airways.

Previous studies designed to test the efficacy of postural drainage in improving ventilatory function have given conflicting and inconclusive results. In this study MEFV curves were measured in order to evaluate more precisely the efficacy of postural drainage in acutely improving flow rates.

MEFV curves were obtained before, 5 minutes after, 15 minutes after, and 45 minutes after a 30-minute session of postural drainage percussion, and vibration in 19 subjects. Nine subjects had cystic fibrosis and 10 had...
chronic bronchitis. At 5, 15, and 45 minutes after drain-
age there was no significant change in FVC, FEV\(_1\), and
FEV\(_1\)/FVC ratio, but there was a significant increase in
isovolume flow rates near 50 percent and 25 percent FVC.

The measurement of \(\dot{V}_{\text{max}} 50\) and \(\dot{V}_{\text{max}} 25\) is a sensi-
tive test for the evaluation of lower airway obstruction.
The significant increase in flow rates at low lung volumes
suggested that postural drainage was effective in mobil-
izing secretions away from the small peripheral airways.
In some subjects, however, isovolume flow near 50 percent
FVC initially decreased from the control values, probably
as a result of airway obstruction by sputum that was
mobilized from small peripheral airways into larger cen-
tral airways.

At 5 minutes after drainage PEFR tended to de-
crease, but by 45 minutes after drainage there was a
tendency for PEFR to increase or return to pretreatment
control values. These data can be attributed to the fact
the PEFR is effort-dependent and is influenced to a great
extent by the resistance of large proximal airways.
Immediately after drainage many of the patients with
chronic bronchitis appeared fatigued and short of breath,
and therefore their ability to generate flow was reduced.
Mobilization of secretions into large central airways may
also have contributed to the initial decrease in PEFR.
The increase in PEFR at 45 minutes after drainage can be
attributed to a reduction in fatigue and to further expectoration of mucus from the large central airways.

The data provide health professionals with further insight into the effects of postural drainage on airflow and have clinical implications for the administration and evaluation of postural drainage. Fatigue, shortness of breath, and wheezing can initially mask postdrainage improvement in flow rates. The nurse may be able to minimize these untoward effects by: (1) administering pharmacologic agents to promote bronchodilation before the postural drainage procedure, (2) allowing the patient to rest as needed between the various positions used during the drainage procedure, and (3) by planning for a period of rest for 30 to 60 minutes after postural drainage, during which time the patient must be encouraged to cough and expectorate the mobilized sputum. Health professionals must also be mindful of the fact that clinical evaluation of this form of therapy can be very misleading especially in terms of the sputum volume produced and the patient's subjective impressions of his ability to breathe more easily.

Hopefully this investigation will provide an impetus toward further research on the effects of postural drainage on airflow. Repetition of this investigation is needed. In addition, further studies need to be attempted in which the MEFV curve would be utilized to (1) evaluate
postural drainage in patients with the primary diagnosis of emphysema, asthma, bronchiectasis, or pneumonia; (2) evaluate the combined effects of bronchodilators and postural drainage in contrast to either alone; (3) evaluate how frequently postural drainage should be prescribed by measuring MEFV curves three to four hours after postural drainage or until such time as flow rates would begin to fall to predrainage levels; and (4) evaluate changes in airflow after the performance of forced vital capacity maneuvers in order to determine more specifically their effect on airway resistance.
APPENDIX A

SUBJECT’S CONSENT

Summary of Research Procedures and Demands in Lay Language

Project Title: Changes in Maximal Expiratory Flow Volume Curves After Postural Drainage in Patients With Cystic Fibrosis or Chronic Bronchitis

I, Jill Feldman, R.N., am a graduate student in Nursing at The University of Arizona. I am conducting a study about changes in breathing tests after postural drainage. Many patients say they can breathe more easily after postural drainage and some say they feel it makes it harder for them to breathe. I am interested in recording the changes in your breathing test measurements after you undergo postural drainage so that you and your nurses and doctors can better determine the effect the treatment has on your breathing.

Your participation in this study will require a total of two to three hours of your time. It will consist of undergoing a 30- to 45-minute session of postural drainage. During the drainage session, you will be asked to assume six different positions for five minutes each and to allow me to perform percussion and vibration on your chest in each position. You will be asked to cough after each position and you will be allowed to rest for short intervals as needed. Immediately before, 5 minutes after, 15 minutes after, and 45 minutes after the postural drainage treatment you will be asked to perform a simple breathing test. Each breathing test involves performing two forceful and complete expirations into a recording device.

On the day prior to the study, you will be asked to collect, in a container I will give you, all your sputum for 24 hours. On the day of the study, you will be asked to abstain from using aerosol and positive pressure breathing treatments for at least four hours prior to the postural drainage treatment and to abstain from postural drainage for at least six hours prior to the treatment. Your participation also includes permitting the investigator to record pertinent information from your chart,
and on the day of the study you will be asked to answer a few questions about your routine respiratory therapy.

You can be assured of the confidential handling of the information obtained in this study. Your name will not be used. The information will be recorded and analyzed by a computer.

There are no known medical, social, or psychological risks involved in participating in this study and there is no additional cost to you for your participation. Since you have participated in postural drainage before and have had the breathing test before, you are aware of the temporary physical discomforts that can occur. They include: feeling of fullness in the head, increased difficulty breathing, and tiredness. Temporary difficulty in breathing may result from positioning and/or the movement of secretions in the airways. It can be relieved by coughing up sputum and resting.

One of the benefits of the study will be the demonstration of a way of further evaluating the effects of postural drainage on breathing in patients with lung disease such as yours. Physicians and nurses will be able to more rationally prescribe the therapy to patients with lung disease.

If you decide not to participate in the study, it will not change your relationship with any doctor or nurse or affect the quality of your treatment or care. I will answer any questions you may have about the study at any time and you may withdraw from the study at any time.

If you understand what is involved and you consent to participate in this study, please sign your name below.

The nature, demands, risks, and benefits of the project have been explained to me and I understand what my participation involves. Furthermore, I understand that I am free to ask questions and withdraw from the project at any time without affecting my relationship with any institution or person.

Subject's Signature: ____________________________
Signature of Parent or Legally Authorized Representative: ____________________________
Relationship: ____________________________
Date: ____________________________
I have carefully explained to the subject the nature of the above project. I certify that to the best of my knowledge the subject signing this consent form understands clearly the nature, demands, benefits, and risks involved in his participation in this study. A medical problem or language or educational barrier has not precluded a clear understanding of his/her involvement in this project.

Investigator's Signature: ____________________________

Date: ____________________________
APPENDIX B

LETTER GRANTING APPROVAL FOR RESEARCH

THE UNIVERSITY OF ARIZONA

ARIZONA MEDICAL CENTER
TUCSON, ARIZONA 85724

College of Medicine

Human Subjects Committee

Address:
Milan Novak, M.D., Ph.D., Chairman
Division of Respiratory Sciences
Arizona Medical Center
882-6115

July 23, 1975

Jill Feldman
College of Nursing

Dear Ms. Feldman:

The Human Subjects Committee has reviewed and approved your proposal entitled "Changes in Maximal Expiratory Flow Volume Curves After Postural Drainage in Patients with Cystic Fibrosis or Chronic Bronchitis," effective July 23, 1975.

The Human Subjects Committee is available to consider any problems which might arise with regard to the use of human subjects, and further you are advised that any changes from the procedures proposed in your project as approved require review by the Committee. You must also report to the Committee any physical or psychological injury to the subjects which results from their participation in the project.

If we can be of further assistance in this or other matters, please feel free to call or write. For future
reference, your proposal has been assigned file number 75-96.

Sincerely,

s/ Milan Novak

Milan Novak, M.D., Ph.D., Chairman
Human Subjects Committee

MN:pv

cc: Gayle Traver, R.N., M.S.N.
    Dr. Kassander
    Dr. Witte
APPENDIX C

DATA COLLECTION SHEET

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<th>Ht.</th>
<th>Sex</th>
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**Diagnosis:**
1. CF
2. GB
3. GB and Emphysema
4. CHF
5. Cor pulmonale
6. COPD

**Physical Findings:**

**Chest X-Ray (date):**

**Blood Gases (date):**
- pH
- PaO_2
- PaCO_2
- O_2 sat.
- HCO_3^-

**Medications:**

**Smoking History:**

**Clinical Score:**

**Sputum:**
- Amount during postural drainage
- Consistency M___ P___ MP___

**Respiratory Therapy:**
- Time since last bronchodilator
- Time since last IPPB
- Time since last aerosol
- Time since last postural drainage
- Frequency of postural drainage at home
- Duration of postural drainage at home
# MEFV Samples

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<th>FVC</th>
<th>FEV₁/FVC</th>
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## Legend of Samples

- **Sample #**: Time:
  - 1: immediately before postural drainage
  - 2: 5 minutes after postural drainage
  - 3: 15 minutes after postural drainage
  - 4: 45 minutes after postural drainage
APPENDIX D

EACH SUBJECT'S PERCENT CHANGE FROM BASELINE FOR PEFR, FEV₁, FVC, AND FEV₁/FVC RATIO AT EACH TIME
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<th>45</th>
<th>5</th>
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A = Cystic Fibrosis
B = Chronic Bronchitis
*Minutes after postural drainage
APPENDIX E

EACH SUBJECT'S PERCENT CHANGE FROM BASELINE FOR ISOVOLUME FLOW AT EACH TIME
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**Mean**

|          | -8      | +7      | +13     | +12     | +34     | +54     |

A = Cystic Fibrosis  
B = Chronic Bronchitis  
*Minutes after postural drainage
SELECTED REFERENCES


