JOHN HUTCHINSON'S MYSTERIOUS MACHINE

THOMAS L. PETTY*, **

DENVER

John Hutchinson, a surgeon invented the spirometer. He coined the term, vital capacity, i.e., the capacity for life. John Hutchinson was a very precise man and a violinist of some reputation. His exacting observations allowed him to learn that the vital capacity was directly related to height and inversely related to age. In his first paper published in 1846 he reported on measurements in 2,130 individuals including deceased patients (1). He recognized that reductions in vital capacity predicted premature morbidity and mortality. Hutchinson became a consultant to the insurance industry of London and he felt that the vital capacity should be used in actuarial predictions. Hutchinson's invention was initially acclaimed. "We have no hesitation in recording our deliberate opinion, that it forms one of the most valuable contributions to physiological science that we have seen for some time. In all future investigations, the name of Mr. Hutchinson must receive honorable notice" (2).

But Hutchinson's instrument (Figure 1) was not widely accepted in London or anywhere else and still remains absent from most physicians' offices and clinics. Since this is so, it is reasonable to conclude that John Hutchinson was frustrated when he left his wife and three children and emigrated to Australia at age 41. At this time, he abandoned all further scientific study of his device. Toward the end of his life he moved to Fiji where he died at age 50, possibly from tuberculosis.

In 1980 it was reported that the vital capacity was a powerful prognostic indicator in the Framingham study of 5,209 men over the age of 30. "This simple office procedure is a useful predictor of pulmonary disease and cardiac failure and can effectively select groups of persons destined for premature death. Since the vital capacity predicts cardiovascular as well as noncardiovascular mortality this pulmonary function measurement seems truly a measure of living capacity useful for insurance and underwriting purposes" (3).

If the vital capacity is so important in clinical medicine, why don't all physicians have a spirometer in their offices just as they have a sphygmomanometer, an EKG machine, a clinical thermometer and a tape measure? This presentation explores this question. Could it be that

---

* Director, Webb-Waring Lung Institute, University of Colorado.

** Address reprint request to the author at the Health Sciences Center, Denver, Colorado 80262.

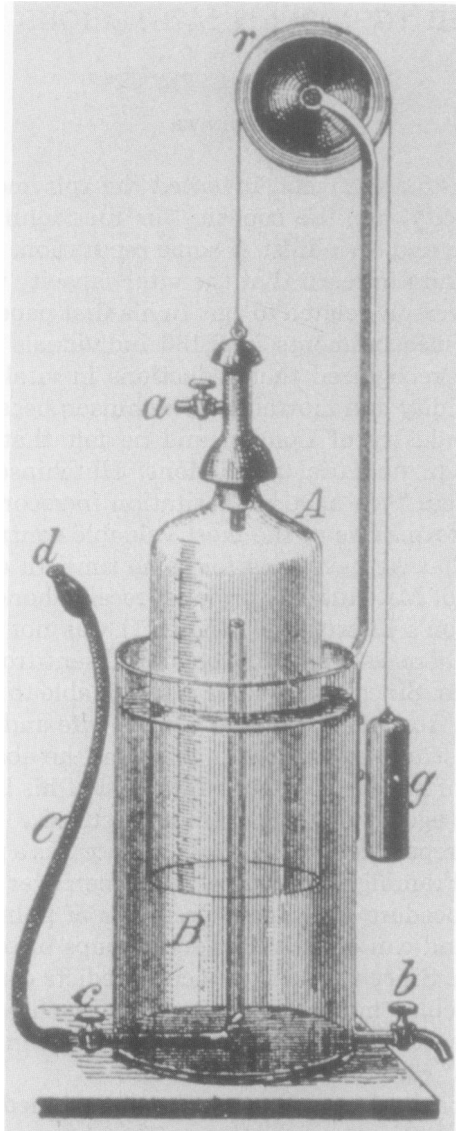

FIG. 248.—WINTRICH'S MODIFICATION OF HUTCHINSON'S SPIROMETER. (*Reichert.*)

FIG. 1. The modification of the original Hutchinson Spirometer. This is a counter balance water seal spirometer, nearly identical in design to modern laboratory standards, e.g., Collins 13.5 liter spirometer. Vital Capacity is a function of volume displacement.

pulmonologists and others with established pulmonary function laboraories are to blame? If so, "we have found the enemy, and he is us!" (borrowed from the comic strip *Pogo*)

SPIROMETRY AND CHRONIC OBSTRUCTIVE LUNG DISEASE

There is absolutely nothing that is complicated about spirometry. Spirometry measures airflow from fully inflated lungs over time in liters. Flow is liters per second. Thus the forced vital capacity (FVC) is the amount of air exhaled from fully inflated lungs as Hutchinson described. A flow test, forced expiratory volume in one second (FEV_1) measures the airflow during the first part of the forced vital capacity maneuver (4). The FEV_1 was the most practical indicator of prognosis in chronic obstructive pulmonary disease (5). It is the best indicator of bronchodilator responsiveness (6). Although many additional airflow tests have been introduced into medicine to determine subtle or early stages of chronic obstructive pulmonary disease, at this writing none are superior to the FEV_1 in assessing abnormalities in airflow or their reversibility, in my opinion. This statement is based on the fact that the FEV_1 was an excellent clinical predictor of prognosis in a large population study (5). In addition, our own work correlating airflow abnormalities with structural changes in whole excised human lungs demonstrated that the FEV_1 was at least as good as other indicators of pathologic changes of alveolar walls or small airways (7). A recent consensus conference on COPD concluded that the FEV_1 is a highly practical and reliable indicator of prognosis and pathology of the lungs in all stages in the development of chronic obstructive pulmonary disease (8).

SPIROMETRY IN THE ASSESSMENT OF HEART FAILURE AND PULMONARY CONGESTION

Several articles have clearly shown the forced vital capacity is an excellent method of detection of left heart failure (9, 10). Recently it has been learned that abnormalities in vital capacity and other lung volumes correlate well with pulmonary artery wedge pressure in heart failure. Serial measurements of FVC have been used to track the course of congestive heart failure and its recovery. Of probably greater importance is the fact that vital capcity could be used to predict congestive heart failure in the Framingham Study (10). A persistently low or recent fall in vital capacity was a clear predictor of future heart failure even after taking into account other contributing factors including blood pressure, relative weight, pulse rate, cigarette smoking, heart enlargement, evi-

dence of left ventricular hypertrophy by EKG, blood glucose and age. The author concluded, "The simple total vital capacity does appear to have considerable utility as a practical, non-invasive office procedure for evaluating failing left ventricular performance" (10). These authors concluded that, "Pulmonary function testing may provide objective, accurate and useful information in the evaluation of cardiac patients for left heart failure" (10). Another important study demonstrated a correlation between reductions in vital capacity and elevated pulmonary artery wedge pressure in patients with congestive heart failure (1) and other states where pulmonary congestion is common, e.g., renal failure can also be monitored by measurements of vital capacity (12, 13).

SPIROMETRY AS A PREDICTOR OF LUNG CANCER

At least two epidemiological studies have shown that abnormal pulmonary function tests indicate a population at far higher risk for lung cancer than in age matched smokers with normal pulmonary function (14, 15). This led to the suggestion that, "The determination of lung function may be used to aid in the assessment of risk of subsequent lung cancer (in smokers) as well as in the assessment of the overall prognosis with respect to survival" (15).

SPIROMETRY IN NEUROMUSCULAR DISEASES

Spirometry can be used to measure and monitor respiratory muscle weakness as in progressive muscular dystrophies, acute Guillain-Barré Syndrome and myasthenia gravis.

SPIROMETRY AS A PREDICTION OF MORTALITY

The Framingham Study clearly showed that abnormalities in forced vital capacity correlated with overall mortality (3). Another 24 year longitudinal study of 874 male volunteers in the study of aging also showed that the ratio of forced expiratory volume in one second to its predicted value was significantly associated with mortality from all causes (16). "Individuals with poor pulmonary function showed greater mortality during the followup period of this study." This relationship was also seen among never smokers in this sample, further supporting the hypothesis that impaired pulmonary function is itself a predictor of total mortality and may contribute to a number of disease processes" (16).

"WHITHER PULMONARY FUNCTION TESTING?"

If simple spirometry is so valuable in assessing the stages of the prognosis and treatment of chronic obstructive pulmonary disease, the

prediction, course and prognosis of heart failure and overall mortality, why have pulmonary function tests been so low to be accepted as practical office procedures? In an authoritative statement of the American College of Chest Physicians, simple practice office spirometry was advised for all primary care physicians nearly a decade ago (17). However recent estimates strongly suggest that no more than 20–30% of primary care physicians have a spirometer in their office or regularly use one. It is much more common for a patient to be referred to pulmonary function laboratories for detailed pulmonary function testing. At least one expert pulmonologist joins me in a scathing criticism of "a panoply of tests with a long printout of results" (18).

It is my contention that the mysteries of the pulmonary function laboratory and the computer printout of an endless set of numbers from the expiratory flow maneuver have served to confuse the practicing clinician and continue to obscure the value of simple measurements of airflow and volume as part of the assessment of all patients in all physicians' offices. I have even suggested that a "financial imperative" is at work to continue this conspiracy of mystique to the detriment of progress (19).

In the continued effort to convince doctors and patients alike of the value of simple spirometry, I often like to quote from Dr. Peter Macklam and Solbert Permutt's excellent book, *The Lung in Transition from Health to Disease* (20). In their book, these two respected clinical physiologists offer an interesting commentary on the lack of widespread use of clinical spirometry in physicians offices including this:

"In considering the simplicity of determination of FEV_1 and its potential use in detecting individuals who are headed toward serious trouble at a time when intervention might have prevented a disastrous outcome, it is interesting to explore the reasons why the spirometer has not achieved a position comparable to the clinical thermometer, the sphygmomanometer, the ophthalmoscope, the chest x-ray and the EKG ....."

And perhaps one of their most profound chastisements is:

"Perhaps even greater responsibility for the near absence of the use of pulmonary function in the prevention of chronic airflow limitation must be borne by the *expert* (italics mine) in pulmonary medicine and especially in his relation to the non-specialist" (20).

WHERE DO WE GO FROM HERE?

There can no longer be any doubt that measurements of FVC and FEV_1 are relevant to the practice of medicine and indicators of chronic lung disease, actual or preexisting congestive heart failure and premature

mortality from all causes. Thus these tests should be part of the data base of all patients or at least those at risk of chronic heart and lung disease or lung cancer based on smoking history or family history. If it is not possible to teach medical students, interns and residents or practicing physicians the value of spirometry, a unique opportunity in prevention of disease will be lost. Already two studies have shown that knowledge of pulmonary function abnormalities can be a powerful motivator in smoking cessation (21, 22). The calculation of lung age, i.e., the impairments due to premature aging of the lung judged by pulmonary function could be another potent motivator for those who continue to deny that their smoking is harmful to their health (23). It has already been established that patients with mild abnormalities in middle age can prevent the disease related decline in ventilatory function as judged by

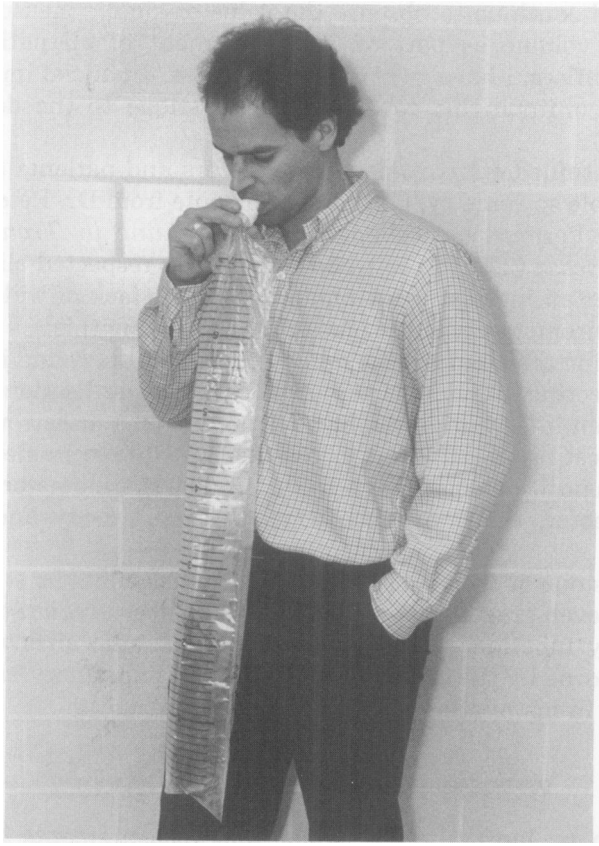

FIG. 2. Simple disposable Vitometer which accurately reflects vital capacity (25). (Reproduced with permission, *Respiratory Care.*)

FEV_1 if they stop smoking (24). Smokers who quit return to the decrement associated with aging compared to smokers who continue to smoke; these persons reveal a continued decline at the disease (COPD) related rate (24). Even patients in their 60s with major losses of ventilatory function survive longer after smoking cessation compared to those who continue this destructive practice (24).

But if we can't promote the notion of even simple time volume tests, what else can we do? Although it would not be my first choice, I would at least promote the use of a simple disposable indicator of vital capacity (25) (Figures 2, 3). This device has been shown to process accuracy within

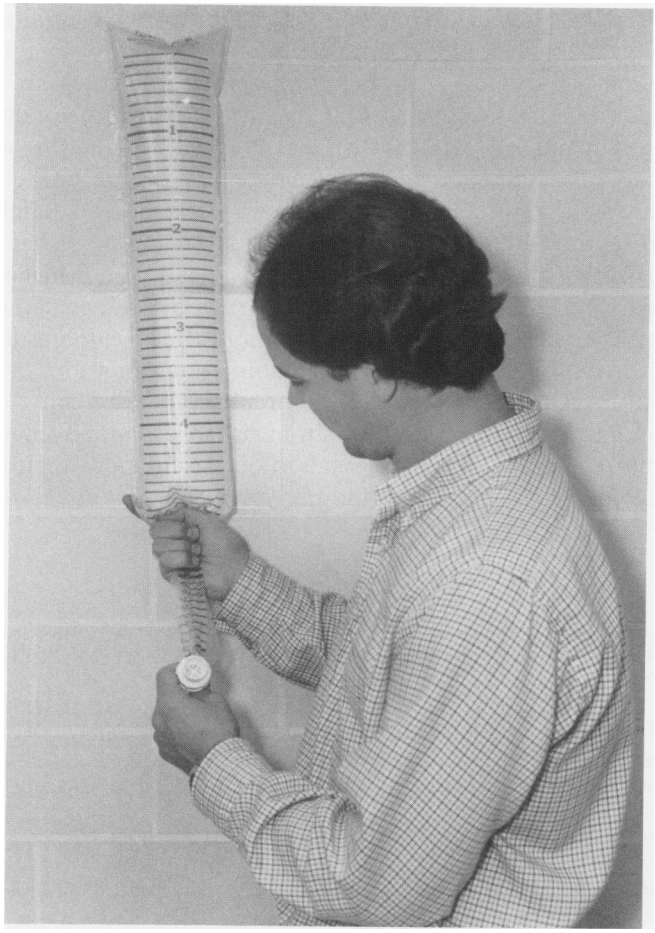

FIG. 3. Medical student demonstrating his own forced vital capacity of 4.9 liters (ATPS). (Reproduced with permission, *Respiratory Care*.)

TABLE 1
Possible Applications for Simple Spirometry to Measure Vital Capacity

• Serial FVC Measurements in
Marathon runners
Alpine climbers
• Monitoring
Pregnancy with heart failure
Progressive neuromuscular disorders
• Assessment of Treatment
Respiratory muscle training
Nocturnal ventilation in states of respiratory muscle fatigue

5% of a laboratory standard spirometer (25). At least physicians could assess the risk of premature morbidity and mortality by serial recordings of forced vital capacity. It does not take a great deal of imagination to list numerous additional applications. Some possibilities are listed on Table 1. For airflow, I would promote the use of simple peak flow meters (26). Peak flow meters do not measure FEV_1 but they measure a function of it. In a given individual measurements of peak flow will track the FEV_1 in a very accurate manner. Peak flow meters are also highly useful in monitoring diurnal variation of airflow in asthma and other disorders and in assessing bronchodilator responsiveness. Thus armed with a vitometer and peak flow meter, the modern practitioner could at least avail himself of the knowledge and wisdom of the late John Hutchinson and, in addition, have at least a reasonable approximation of the effectiveness of bronchodilators in his daily practice. A "hard copy" of volume and flow and its evolution over time, from simple office spirometry, would be even more valuable in the assessment of patients and their prognosis in chronic lung disease, heart failure, lung cancer and as an overall predictor of mortality.

REFERENCES

1. Hutchinson J. On the capacity of the lungs and on the respiratory function with a view of establishing a precise and easy method of detecting disease by the spirometer. *Med Chir Tr (London)* 1846; 29: 137.
2. Bishop PJ. A bibliography of John Hutchinson. *Med Hist* 1977; 21: 384.
3. Kannel WB, Lew EA, Hubert HB, et al. The value of measuring vital capacity for prognostic purposes. *Trans Am Life Ins Med Dir of Am* 1980; 64: 66.
4. Gaensler EA. Analysis of the ventilatory defect by timed vital capacity. *Rev Tuberc* 1951; 69: 256.
5. Higgins MW, Keller JB, Becker M, et al. An index of risk for obstructive airways disease. *Am Rev Respir Dis* 1982; 125: 144.
6. Light RW, Conrad SA, George RB. The one best test for evaluating the effects of bronchodilator therapy. *Chest* 1977; 72: 512.
7. Petty TL, Silvers GW, Stanford RE. The morphology and morphometry of small

airways disease. (Relevance to chronic obstructive pulmonary disease). *Trans Am Clin Climatol Assoc* 1982; 94: 130.
8. Snider GL, Kleinerman J, Thurlbeck WM, et al. The definition of emphysema. Report of a National Heart, Lung, and Blood Institute, Division of Lung Diseases Workshop. *Am Rev Respir Dis* 1985; 132: 182.
9. Levine SA. The value of determination of the vital capacity of the lungs in the care of patients with heart disease. *Arg Bras Cardiol* 1949; 2: 253.
10. Kannel WB, Seidman JM, Fercho W, et al. Vital capacity and congestive heart failure. The Framingham Study. *Circulation* 1974; 49: 1160.
11. Ries AL, Gregoratos G, Friedman PJ, et al. Pulmonary function tests in the detection of left heart failure: Correlation with pulmonary artery wedge pressure. *Respiration* 1986; 49: 241.
12. Robson M, Levin S, Ravid M. Serial measurement of vital capacity in patients in chronic hemodialysis. *Nephron* 1977; 19: 60.
13. Zidalka A, Despas PJ, Milie-Emili J, et al. Pulmonary function with acute loss of excess lung water by hemodialysis in patients with chronic uremia. *Am J Med* 1973; 55: 134.
14. Cohen BH, Graves CG, Levy DA, et al. A common familial component in lung cancer and chronic obstructive pulmonary disease. *Lancet* 1977; 2: 523.
15. Skillrud DM, Offord KP, Miller RD. Higher risk of lung cancer in chronic obstructive pulmonary disease. *Ann Intern Med* 1986; 105: 503.
16. Beaty TH, Newill CA, Cohen BH, et al. Effects of pulmonary function on mortality. *J Chron Dis* 1985; 38: 703.
17. Permutt S, Chester E, Anderson W, et al. Office spirometry in clinical practice. *Chest* 1978; 74: 298.
18. Williams H. The pulmonary function laboratory—who needs it? *Chest* 1986; 89: 769.
19. Petty TL. New technology and the financial imperative (A commentary on outreach for office spirometry). *Resp Care* 1984; 29: 890.
20. Macklem P, Permutt S. *The Lung in Transition from Health to Disease.* New York: Marcel Dekker; 1979.
21. Petty TL, Pierson DJ, Dick NP, et al. Follow-up evaluation of a prevalence study for chronic bronchitis and chronic airflow obstruction. *Am Rev Respir Dis* 1976; 114: 881.
22. Hepper NGG, Drage CW, Davies SF, et al. Chronic obstructive pulmonary disease: A community oriented program including professional education and screening by a voluntary health agency. *Am Rev Respir Dis* 1980; 121: 97.
23. Morris JF, Temple W. Spirometric "lung age" estimation for motivating smoking cessation. *Preventive Med* 1985; 14: 655.
24. Peto R, Speizer FE, Cochrane AL, et al. The relevance in adults of airflow obstruction, but not of mucus hypersecretion to mortality from chronic lung disease: Results from 20 years of prospective observation. *Am Rev Respir Dis* 1983; 128: 491.
25. Anders AJ, Baidwan B, Petty TL. An evaluation of the vitometer. A simple device for measuring vital capacity. *Resp Care* 1984; 84: 1144.
26. Eichenhorn MS, Beauchamp RK, Harper PA, et al. An assessment of three portable flow meters. *Chest* 1982; 82: 306.

DISCUSSIONS

Calkins (Buffalo): I'm really intrigued by your definition of vital capacity as the capacity to survive. In geriatric medicine the feeling is emerging that people indeed do die of old age—if cancer or heart disease or strokes or what-not do not intercede. The normal maximal achievement of life is around 95 years. There's a feeling that what finally tolls the bell is

inability to get enough oxygen to keep going; again, suggesting it is the vital capacity, capacity to live. In your list of conditions that you think this could be followed you didn't happen to mention just geriatric medicine, pursuing the course of patients as they grow older. Do you have any feeling yourself, in fact, in people that do not develop these other diseases but just kind of keep going until they poop out, that it is the lack of oxygen exchange that might toll the bell or is that perhaps just something that I picked up along the line that is perhaps not valid.

Petty: Thank you, Dr. Calkins. I think that's interesting and correct and there's something I'd like to add to that. It's well known that these measurements, including the forced vital capacity go down with age, but they go down very slowly in normal people, until age 50. And then the older you get, the faster they go down, which is of great interest in terms of people looking at longevity. There are a number of studies now serially being made in octogenarians and their rate change of lung function which seems to predict their outcome extremely accurately. In the end of course, without ventilation, there would be oxygen transfer failure.

C. Johns (Baltimore): You obviously did have interstitial lung diseases on your list of detectable and testable diseases. As someone particularly interested in pulmonary sarcoidosis, I'd say that my colleagues are always asking questions about the markers of disease activity. In many of our patients following serial measurements of FEV_1 is extremely helpful in determining whether the disease is stable, getting better or getting worse. I completely agree with the emphasis you've made.

Petty: Thank you very much Carol. I'd like to point out that in addition, in AIDS pneumonia—something that is just beginning in epidemic proportions—the outcome in terms of nosocomial pneumonias is exactly predicted by changes in the forced vital capacity. Better than any other test.

Barondess (NY): Tom, could I ask you whether the falloff in this function with age appears to be entirely a function of loss of elastic recoil in the lung and whether that is a reflection of change in elastic tissue generally throughout the body as a function of age? It certainly appears to be measureable in the aortic wall. I wonder if you would know of any measures elsewhere of the status of the recoil capacity of elastic tissue in other structures, with age.

Petty: We have data on that in excised human lungs in patients over the age of 80 and in fact a reduced vital capacity is indeed a very close function of loss of elastic recoil. I do not have it in correlation with loss of elasticity of other organs. There is a correlation between vital capacity and survival after the patient gets pneumocystis carinii pneumonia. That is the best index of either improvement in response to therapy or predictive of mortality in AIDS patients with this common infection.

Goldfinger (Boston): In this age of interest in procedures on the part of all practitioners it is simply astounding that spirometry has not captured more attention. I wonder what might be the reason. Do you think, for example, that if the procedure might earn $25 instead of $5 it would capture the day?

Petty: Well, I think you're right. What do we do? We perform pulmonary function tests. We schedule the laboratory. We can't get pulmonary functions in the immediate preoperative period because the lab is closed and it should be patently obvious to everyone in the audience that you could get a vital capcity at the bedside extremely easily.