MEDICAL PRACTICE

Contemporary Themes

Ten Years' Experience in Running a Pulmonary Function Laboratory

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Summary

A survey of the development and work of a pulmonary function laboratory in a teaching hospital over a 10-year period has shown an increasing demand for pulmonary function tests from all departments, in particular some of the surgical ones. Though no arrangement for staffing and equipping such a laboratory is ideal quite a lot of useful clinical information can be derived from a few simple tests performed in a central laboratory.

Introduction

Tests of pulmonary function for use in clinical medicine have become increasingly in demand. Their availability is more widespread than before, but the pulmonary function laboratory is still not as prominent as the E.C.G. department in most hospitals. We think that tests of pulmonary function can be most useful in everyday general medicine, where about 25% of patients may present with respiratory illness. Though many laboratories, including our own, have facilities for research this paper presents the everyday experience of running a clinical laboratory in a busy, non-specialist teaching hospital. We hope it will provide a useful basis for those concerned in developing a pulmonary function laboratory service in a general hospital.

Growth of Demand

A pulmonary function laboratory was first set up in this hospital in the 1950s. After the founder's appointment elsewhere it was to some extent run down and was restarted in its present form in February 1962. At that time it was only simply equipped and sited in a small room near the wards. The staff consisted of a single laboratory technician, while the medical supervision came from one of us who was working as a registrar on a busy general medical firm. Hence there was a bias towards entirely clinical problems, particularly those posed by patients with chest or other medical illnesses, as the source of the first year's requests show (see Table). There was little time for innovation of any sort or to develop new techniques. On the other hand, since the number of requests was small it was usually possible to see every patient tested. The tests were simple (spirometry, lung volumes, transfer factor, and rebreathing Pco_2) but it was possible to try to correlate them with the patients' clinical condition and exchange views with the clinicians concerned.

In 1963-4 one of us (D.T.D.H.) went to the U.S.A. as a research Fellow, and after his return there was a steep rise in the demand for tests (see Fig. 1). The work now occupies two

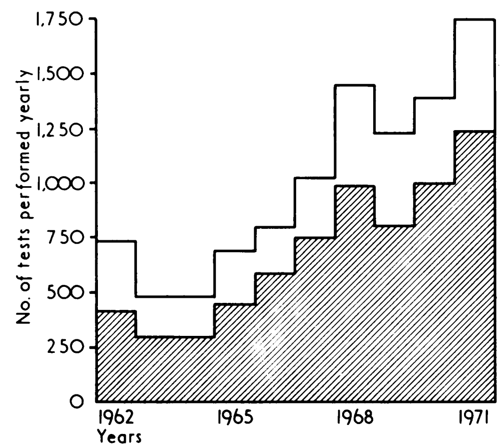

FIG. 1—Number of pulmonary function tests performed yearly during the past 10 years at the London Hospital. Shaded area indicates number of patients who were attending the laboratory for the first time.

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full-time technicians and part of the time of a consultant physician and a research Fellow. Much of this increased demand has come from departments other than those of chest and general medicine. In particular, cardiologists and thoracic and other surgeons have been requesting more tests. In 1962 only 30 patients were referred for preoperative assessment, whereas in 1971 the figure was over 300. In addition several patients have been referred by other hospitals that lack a pulmonary function laboratory of their own (Table). In spite of the increase in medical staff many patients attend when there is no doctor in the laboratory. This may not matter, however, if a suitably designed request form or notes accompanying the patient make clear the clinical problem. In addition the technicians are aware of which tests are relevant for most of the important diseases. Ideally all cases should be seen by a pulmonary physician of at least registrar grade either before or during the tests, but our present compromise is to have a doctor in attendance part of the time and to point out to our colleagues that a request for pulmonary function tests does not necessarily include a clinical opinion.

Source of Cases Referred in 1962 and 1971

	1962		1971	
	No.	%	No.	%
Chest physicians	494	66	525	30
General physicians	120	16	370	21
Thoracic surgeons	23	3	262	15
General surgeons	7	1	53	3
E.N.T. surgeons	7	1	52	3
Cardiologists	67	9	350	20
Rheumatologists	8	1	35	2
Other departments	15	2	70	4
Other hospitals	7	1	33	2
Total	748	100	1,750	100

Types of Assessment Required

Patients are referred to the laboratory for five main reasons.

Diagnosis.—The cause of breathlessness is not always clinically obvious and differential diagnosis is an important indication for performing lung function tests. In patients with elements of both pulmonary and cardiac disease pulmonary function tests can be useful in assessing which is making the larger contribution to the breathlessness. Asthma, chronic bronchitis, and emphysema can often be differentiated by simple lung function tests. Often patients with these diseases are found to be much worse on testing than might have been suspected clinically. Sometimes patients with "functional dyspnoea" are seen. Mostly these patients hyperventilate with a low P_{CO_2} and a very irregular breathing pattern.

Objective Assessment of Deranged Function.—It is always useful to have objective measurements of function in medicine so that changes can be recorded over time. Deterioration can then easily be detected and responses to treatment monitored. Patients with asthma or sarcoidosis receiving steroids have serial studies performed to assess their progress by objective means. In addition several compensation cases are dealt with, often concerning asbestosis. Supporting evidence of this diagnosis and an assessment of the degree of impairment may be provided by a pulmonary function profile.

Preoperative Assessment.—The main group of patients in this category are those about to have thoracic surgery. One cannot always predict when a lung resection is going to lead to respiratory insufficiency, but certainly many patients who would not survive long afterwards because of pre-existing lung disease can be saved. the unnecessary suffering of a major operation. Our criteria are generally that the patient needs a vital capacity of more than 2·5 litres, provided that the tumour is not obstructing a major bronchus, together with a normal arterial P_{CO_2} (less than 45 mm Hg) if pneumonectomy is contemplated. The criteria are less strict if lobectomy is planned but warning can still be given of possible respiratory failure. Airways obstruction is not taken as a contraindication to surgery if these criteria are satified but delay may be recommended to allow for a period of medical treatment, including physiotherapy. This also applies to patients undergoing other operations when preoperative preparation may prevent pulmonary complications after the operation.

Management of Respiratory Failure.—Serial measurements of arterial blood gas tensions and pH are essential for the management of respiratory failure, and in particular a rising P_{CO_2} can be detected at an early stage. If an electrode system is not available serial rebreathing P_{CO_2} estimations are an alternative (see below).

Assessment of Ventilatory Function in Extrapulmonary Diseases.—These include neurological diseases and drug overdosage. Examples of the former are Guillain-Barré paralysis and myasthenia gravis, which may usefully be assessed by serial routine tests. Myotonia dystrophica is also often associated with impaired lung function.[1]

Types of Test

ROUTINE TESTS

Patients coming to the laboratory with a request for standard pulmonary function tests have the following tests performed. (The equipment used is described in the Appendix, as indicated by the figures in parentheses.)

Vital Capacity (VC) and Forced Expiratory Volume in One Second (FEV_1).—A Vitalograph spirometer (1) is used and three recordings of VC are made.[2] The patient is then instructed to exhale with maximal effort, and three recordings of FEV_1 are made. The best reading is taken for each and converted to body temperature, pressure, and saturation (B.T.P.S.) by the use of tables.

Peak Expiratory Flow Rate (PEFR).—This is recorded with the use of Wright's peak flow meter (2), and again the best of three efforts is taken as the correct reading. This test is more effort-dependent than the FEV_1, and extra care must be taken to ensure that maximal expiratory effort is achieved after a full inspiration.[3]

Effect of a Bronchodilator.—If the VC, FEV_1, and PEFR are reduced below normal they are again estimated after 0·16 mg of isoprenaline has been administered by aerosol spray (3). Isoprenaline is the agent of choice because of the rapid onset of its effects. Ten minutes is a suitable time to allow for showing a reversible element in airways obstruction.

Rebreathing P_{CO_2}.—The method described by Campbell and Howell[4] determines the mixed venous P_{CO_2}. The percentage of carbon dioxide in the rebreathing bag is estimated by a rapid-reading infra-red CO_2 analyser (4). This is regularly calibrated by a chemical method with use of the simplified Haldane apparatus (5). Using the percentage value and the barometric pressure the mixed venous P_{CO_2} is calculated, and 6 mm Hg can be subtracted from this figure to express the result as "arterial" P_{CO_2}. This is satisfactory at nearly normal levels but the relation of mixed venous to arterial P_{CO_2} is less constant when the values are higher than normal.

Roughly 20 minutes of patient's time is required to perform these simple tests and a large amount of useful information can be derived from them. They suffice in about 70% of cases referred to the laboratory, but the following special tests are performed when indicated.

SPECIAL TESTS

Transfer Factor (Diffusing Capacity).—This is estimated twice by the single-breath carbon monoxide method using a Resparameter (6).[5] If technically satisfactory the mean result is taken (patient's time 5-10 minutes).

Lung Volumes.—The helium dilution method using a Godart Pulmotest (7) is employed to estimate functional residual capacity[6] (patient's time 10 minutes). In addition residual volume, total lung capacity, and VC are calculated.

Skin Allergy Tests.—Skin tests are performed when requested on patients with asthma or allergic rhinitis. The technicians carry out and read prick-tests with 14 allergens commonly involved in pulmonary disease (see Appendix). A few intradermal tests are used when indicated—for example, chicken or budgerigar feathers—and more specialized prick-test solutions are available—for example, dry rot, teak extract—if required. (Patient's time 15 minutes.)

Blood Gases.—The pH, Po_2, and Pco_2 of arterial blood are measured with direct-reading electrodes (BMS 3) (9) in association with a scale-reading meter. We also have an older Astrup microtonometer system with a separate Po_2 electrode which has to date, proved slightly more reliable. This model (AMT 1) has been discontinued but the BMS 2 (10) uses the same principle. This system is more tedious, however, as the calculation of Pco_2 depends on pH measurements before and after tonometry of the blood with two gas mixtures.

Research Equipment.—We also have a constant volume body plethysmograph (11) to measure airways resistance and thoracic gas volume, pneumotachographs with integrators to measure flow rates and volumes (12), a rapid oxygen analyser (13), and a bicycle ergometer. These are used for special projects, but if medical manpower permits exercise and plethysmograph studies can be of value in some routine cases. The transducer and pneumotachograph from the plethysmograph can be used to measure compliance. Previously a Statham PM 6 differential strain gauge and spirometer were used.

Presentation of Results

The normal values for all tests are predicted by nomograms[7] which allow for age, height, and sex. The results for each patient are presented both as absolute values and as percentages of predicted normal. A report is written by a doctor who interprets the results, and when necessary the patient may be seen clinically beforehand. The results and report are recorded on a permanent index card for filing. A record for the notes is sent to the ward or clinic on the same day as the tests are performed (Fig. 2). We do not usually include the Vitalograph charts with the reports.

FIG. 2—Record Sheet completed by Doctor and sent to Ward or Clinic on Day of Tests.

The London Hospital

PULMONARY FUNCTION LABORATORY

Name:	Ward:	Unit No:
Age:	Date:	Lab. No:
Sex:	Height:	Clinical Diagnosis:

	Observed	Predicted	% Predicted	After Isoprenaline	% Change
Vital Capacity (ml) FEV1 (ml) . . FEV% . . . . Peak Flow (l/min) Transfer Factor (ml/min/mm Hg)					
Rebreathing Pco_2	Mixed venous =	mm Hg		"Arterial" =	mm Hg
Skin Tests					

Staffing

MEDICAL

The laboratory is supervised by a consultant physician with a special interest in chest diseases. He is assisted by a full-time research Fellow who participates in the day-to-day running of the laboratory. All requests are scrutinized by a member of the medical staff to ensure that appropriate tests are performed, and he subsequently writes the reports.

TECHNICAL AND SECRETARIAL

Two full-time laboratory technicians perform most of the tests and do all the record keeping. At present, training of technicians for work in pulmonary function laboratories is not organised on a national basis, although various local schemes are being arranged. In London technicians can take O.N.C. and H.N.C. courses that include medical and physiological measurement. The Zuckerman report,[8] if implemented, will certainly affect the training position. It is quite possible to run a laboratory geared to simple tests for clinical use only with technicians trained only on an "in-service" basis. The drawbacks are that one cannot pay such technicians adequately and that one needs people with higher educational qualifications to deal with the more complex equipment or to take part in research projects. In fact, our technicians have had to be versatile, acting not only as technicians but as secretaries, receptionists, porters, nurses, social workers, and medical artists on occasions. In addition they often have to give "unofficial" reports and advice to members of the medical staff in the absence of a doctor. Versatility is perhaps their most important attribute.

Setting up and Running a Laboratory

Many hospitals have simple equipment for carrying out tests of pulmonary function, such as spirometers and peak flow meters. The *minimum equipment* required is probably these two plus Campbell and Howell rebreathing CO_2 bags with a Haldane apparatus. Though these can all be used by relatively unskilled personnel their value is much enhanced by having them in regular use by one technician with one doctor responsible. This ensures that the equipment is properly maintained (the potassium hydroxide spills over easily in the Haldane apparatus), makes sure that it is working and properly calibrated, and means that any results obtained can be interpreted by an expert and are reported and filed in an orderly manner. Tests carried out once a week by a nurse or an E.C.G. technician on a broken apparatus cannot possibly mean much.

This basic equipment is quite adequate to make a start. It enables one to tell if a patient has airways obstruction, how severe it is, and whether it is reversible; also to see whether carbon dioxide retention and hence respiratory failure is present. In 70% of hospital patients referred for routine testing this may be sufficient, and all the tests can be used at the bedside if necessary. These together with a typewriter and a record system can be housed in a relatively small room. The equipment costs under £200 and apart from salaries the running costs would be low (see Appendix). Obviously as the laboratory develops, so will the range of equipment. A blood gas apparatus is probably the next essential. Problems may arise here as these need constant attention and use by an expert (be it a doctor or a technician), which it may prove difficult to provide if staff are few, especially for emergency work at night. In addition maintenance costs may be high with any model.

Our Pulmotest has been used much less in recent years to measure lung volumes. This is mainly because the body plethysmograph is in many ways a more satisfactory method of measurement. Skin tests are performed to give an indication of the atopic status of the patient. The results may sometimes be used as a guide for specific desensitization, but inhalation challenge tests are more important when this is contemplated.[9] The transfer factor is open to many criticisms[7] but is still a useful clinical test and can be performed accurately with a high degree of reproducability by a good technician. We have found it most useful in assessing the severity of pulmonary involvement in diseases such as scleroderma and disseminated lupus erythematosus and the response of patients with fibrosing alveolitis to treatment.[10]

There is, we think, a place for much greater development of pulmonary function laboratories in general hospitals. The information obtained even with relatively simple equipment is of value to general and chest physicians, anaesthetists, and surgeons in both diagnosis and assessment. For the small capital outlay required the amount of clinically useful information which can be obtained is unparallelled by any other department.

Appendix

APPROXIMATE COST OF EQUIPMENT	£
(1) Vitalograph dry spirometer (Instruction book includes prediction nomograms and correction tables for B.T.P.S.)	97
Stand	30
100 Charts	8
From Vitalograph Ltd., Maids Moreton House, Buckingham	
(2) Wright's peak flow meter	40
From Airmed Ltd., Edinburgh Way, Temple Fields, Harlow, Essex	
(3) Medihaler-Iso	less than 1
From Riker Laboratories, Morley Street, Loughborough, Leics	
(4) Rapid CO_2 analyser (Hartman)	1,500
From P. K. Morgan Ltd., 10 Manor Way, Chatham, Kent	
(5) Simplified Haldane apparatus (Campbell-Howell)	27
From Aimer Products Ltd., 56 Rochester Place, London N.W.1	
(6) Resparameter mark IV	1,950
From P. K. Morgan Ltd., 10 Manor Way, Chatham, Kent	
(7) Godart Pulmotest and helium analyser	1,500
From P. K. Morgan Ltd., 10 Manor Way, Chatham, Kent	
(8) Allpyral allergen extracts (we use routinely control, mold mix, grass mix, nettle, horse epithelia, dog epithelia, house dust, house-dust mite, flower mix, *Cladosporium herbarum*, cat epithelia, feather mix, *Alternaria tenius*, *Aspergillus fumigatus*, tree mix)	20
From Dome Allergy Unit, Stoke Poges, Slough, Bucks	
(9, 10) Blood gas and pH machines:	
BMS 3 (pH, P_{CO_2}, P_{O_2} electrodes with water-bath)	510
PHM 71 meter (scale)	255
PHM 72 meter (digital)	495
	765 or 1,005
BMS 2 (tonometer, water-bath, and pH electrode)	460
PHM 71 meter (scale)	255
PHM 72 meter (digital)	495
	715 or 955
From V. A. Howe Ltd., 88 Peterborough Road, London S.W.6	
(11) Body plethysmograph and respiration computer	12,000
From Erich Jaeger, Wurzburg, Germany	
(12) Pneumotachograph with integrator	560
From Mercury Electronics, 64 Argyle Street, Glasgow	
(13) Paramagnetic oxygen analyser	200
From Servomex Controls Ltd., Crowborough, Sussex	

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Hospital Topics

Causes of Failure in Antibiotic Treatment*

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Accounts of therapeutics are usually a record of success, and anyone who chooses to describe only failures may be thought a pessimist or a cynic. This would be unjust; much can be learnt from failures, and they are often long and vividly remembered. Moreover, to bear in mind causes of failure should enable you to steer a course which avoids them to success.

The causes of failure may be either in the nature of the disease treated or in the choice or mode of use of the antibiotic.

* Based on a lecture given at Mount Vernon Hospital, Northwood, on 14 October 1972.

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Conditions Insusceptible to Treatment

Penicillin is not a panacea for fever. To utter this truism in a country with a relatively good record for discriminating use of antibiotics almost calls for an apology, but the freedom with which they are prescribed or even self-administered in some parts of the world for trivial or inappropriate reasons is deplorable. It is on record in a famous journal[1] that a girl who had been given oral penicillin for earache (twice), for a pain in the knee, and for toothache and went into severe shock after the last dose was under the impression that penicillin is an analgesic. A seriously ill febrile patient may rightly be given an antibiotic on some explicit assumption with regard to the nature of the infection, but only after specimens have been obtained by which this can later be verified. It is a therapeutic crime to begin the treatment of a supposed bacterial endocarditis before blood cultures have been done, since it then becomes difficult to grow the organism and thus determine the proper treatment. Bacteriological diagnosis in purulent meningitis can be hampered in the same way, but in this far more urgent condition the benefit of early treatment may outweigh the drawback of not knowing its cause.