

TSANZ

**RESPIRATORY FUNCTION TESTS
- AND THEIR APPLICATION**

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INTRODUCTION

This document attempts to provide a broad consensus statement about common practice in respiratory function testing and the use of its results in assessing respiratory disease and disability. It is written for respiratory and general clinicians.

General principles only are provided and the source documents are referenced but detail is not exhaustive and technically the document does not attempt to provide best practice guidelines. It is meant to reflect usual practice and in individual patients use of respiratory function tests outside these guidelines may clearly be appropriate in particular clinical circumstances.

General statements about quality assurance and cost benefit will be given at the end of the document but for each individual test there are sections on description, indications, interpretation, normal values, specific quality assurance, and cost benefit. The scope of the document will cover tests of mechanical function, gas exchange and exercise assessment.

The advice of Dr K E Finucane was especially helpful. We are grateful to those many practising respiratory clinicians whose advice and experience were tapped and who played a very significant role in shaping these guidelines.

Although the general principles remain applicable, Paediatric respiratory function assessment has special constraints relevant to smaller children and infants. These have been particularly covered in a TSANZ position paper ².

Assessment of sleep disordered breathing is an area of respiratory function evaluation not covered here. Attention is drawn to the TSANZ document "Guidelines for respiratory sleep studies

"¹ which covers clinical practice in this area.

References

1. Guidelines for Respiratory Sleep Studies. Hillman d et al. TSANZ 1993
2. Pulmonary Function Testing in children. Sly P.D. and Robertson C.F. TSANZ 1988.

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2. CLINICAL APPLICATION

In developing these guidelines it was necessary to consider each respiratory function test in isolation and to give an overview of its uses, indications, limitations and quality assurance considerations. In clinical practice however, tests are used in various combinations to establish the likelihood of particular disease processes and to define their severity and responses to treatment. This is necessary because individual tests give evidence relating to specific *functions* of the lungs rather than specific pathological processes or diagnoses and individual aspects of lung function can be disrupted similarly by different disease processes. To give a more specific indication of disease processes, patterns of abnormality across a range of tests are of critical value.

A good example of this concept is found in our attempts to be more specific about pathological disease processes in patients with smoking related lung disease who present with breathlessness and wheeze. Spirometry will show airflow obstruction (a functional state) in such patients whether they have predominant airway disease, predominant emphysema or both pathologies and is thus of little value in distinguishing between these possible disease processes. This distinction is of considerable clinical importance however in relation to the vigour with which therapy with bronchodilators and steroids should be pursued in the management of the individual patient. Further respiratory function tests are thus often used to pursue the distinction between these two pathological processes.

Absence of bronchodilator response does not exclude chronic airways disease in favour of emphysema. Bronchial hyper-reactivity may be present in chronic airways disease but if absent does not exclude that diagnosis and blood gas analysis will show impairment of gas exchange manifest by widening of the alveolar-arterial gradient in all these conditions. Thus none of these latter tests will be likely to help with specific diagnosis. On the other hand total lung capacity measured in a body plethysmograph is more likely to be increased in emphysema and gas transfer factor (DLCO) measured by the single breath technique is likely to be reduced in emphysema but relatively well preserved in airways disease.

5.

Measurements of lung and airway mechanics require the use of an oesophageal balloon and are thus minimally invasive. The relationship between elastic recoil pressure and lung volume provides information about pulmonary distensibility. Because this relationship is non-linear single values of lung compliance vary with lung volume. The best measures of lung distensibility are derived from exponential analysis of data obtained during interrupted deflation from total lung capacity. The exponent K, equivalent to the bulk elastic modulus, provides the most sensitive index but there is a relatively wide normal range. To distinguish between dynamic and relatively fixed airway narrowing elastic recoil pressure (P_{el} , driving airflow) can be related to airway conductance (G_{aw}) during both tidal breathing and maximal forced expiratory manoeuvres. During tidal breathing the slope of G_{aw}/P_{el} is increased in emphysema and decreased in airway disease.

A great deal of time and research effort over many years has been put into evaluating the relationship between these respiratory function tests and likelihood of specific disease processes. Further ongoing research is required to elucidate and evolve the use of specific respiratory function tests in clinical and therapeutic decision making.

Attempts have been made to distinguish these pathological processes using the shape of the flow-volume curve. Emphysema causes sudden pressure-dependent limitation of maximal expiratory flow with reasonably well preserved maximal inspiratory flow. Airways disease on the other hand causes gradual volume-dependent reduction of maximal expiratory flow and impairs maximal inspiratory flow as well. The ratio of flow volume curve areas of maximal expiratory to maximal inspiratory flow may thus be particularly low in emphysema. Although theoretically plausible, this test has also yet to be demonstrated to be of clinical significance in the discrimination between disease processes.

Studies examining the correlation of all these respiratory function indices against radiologic and pathologic indices of specific disease are currently being performed to determine the sensitivity and specificity of individual respiratory function tests in discriminating between emphysema and airways disease.

A difficulty here is reaching agreement on what is the appropriate gold standard for the diagnosis of emphysema. Thin sections of lung parenchyma obtained at postmortem or on lung resection specimens evaluated by measurements such as mean airspace diameter are probably the best standard we have at present. For meaningful results, these specimens must be inflated with fixative at a pressure of 30cmH₂O. High resolution computed tomography of the lungs, is good for detecting bullous disease but does not have the resolution to give it a high sensitivity for low grades of diffuse panacinar emphysema demonstrable on thin sections of lung parenchyma. The latter however have the problem of sampling bias in that they are not necessarily reflective of the average extent of pathology across the whole lungs as reflected in respiratory function tests and HR-CT.

6.

In the meantime, many clinicians content themselves with the performance of spirometry with assessment of bronchodilator responsiveness and DLCO, often in conjunction with a crude trial of steroid treatment for airways disease. Many will contend that this is all that is needed to manage the majority of patients. While this many yet prove to be the case, the goal of ongoing and further research should be to develop non-invasive respiratory function tests which can discriminate between airways disease and emphysema with sufficient sensitivity to be clinically useful in directing management and improving outcomes.

There are numerous other clinical examples of the complimentary use of the multiple respiratory function tests to try to make a specific clinical diagnoses. To document each of these samples is beyond the scope of this paper. Instead a simple test-by-test approach has been used with emphasis on defining the indications for individual tests as well as those situations in which use of individual tests would be inappropriate.

There are a number of tests which are not covered in these guidelines that are often shared with other disciplines but which may have great clinical value in particular clinical circumstances. Lung perfusion scans and measurements of pulmonary artery pressure respectively in pulmonary thromboembolic disease and COPD are examples of this. Regional lung function tests based on ventilation-perfusion scanning or bronchoscopic lobar gas sampling in patients with lung cysts or lung cancer requiring resection is another. Modified technegas scans used to assess of the integrity of the alveolar capillary membrane function is a further example. The use of such tests in conjunction with more standard lung function tests is often invaluable in clinical decision making in some patients.

Other respiratory function tests, not covered in any comprehensive way here, may have usefulness other than in clinical settings. Measurement of the density dependence of maximal expiratory flow at low lung volumes (volume of iso-flow) and the frequency dependence of compliance are useful tools for detecting the presence of early disease in the “ silent zone “ of the peripheral airways in subjects with normal spirometric indices. These tests may be applicable in population studies and as screening tools in identifying at-risk subjects in specific occupational settings. The wide normal range for these measurements limits usefulness in the clinical setting.

This document aims to provide information about the respiratory function tests used frequently in clinical practice. The focus is primarily on clinical practice rather than on epidemiological or research applications.

7.

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3. TEST OF MECHANICAL FUNCTION

3.1 “ SPIROMETRY “ : VC, FVC, FEV1, maximum inspiratory and expiratory flow rates.

Description

Spirometry is the timed measurement of dynamic lung volumes during forced expiration and inspiration to quantify how effectively and how quickly the lungs can be emptied and filled.

The measurements usually made are the vital capacity (forced and/or unforced), forced expiratory volume in one second and the ratio of these two volumes (FEV1/FVC). Additionally one can measure the maximum expiratory flow over the middle 50% of the vital capacity (FEF25-75%) which is a sensitive index of small airway function.

Measures of forced maximal flow during expiration and inspiration flow can be also made either absolutely eg. peak expiratory flow or as a function of volume thus generating a flow volume curve, the shape of which also contains information of diagnostic value.

Indications

- The detection of respiratory disease in patients presenting with symptoms of breathlessness either at rest or on exertion, wheeze, cough, stridor, etc. Spirometry is useful in distinguishing respiratory from cardiac disease as the cause of breathlessness and can be used to screen for respiratory disease in certain high risk situations, eg. pre-employment in industries in which occupational asthma is prevalent, and to identify those at risk from pulmonary barotrauma whilst SCUBA diving.
- The diagnosis of respiratory disease and differentiation of obstructive versus restrictive ventilatory defects, the identification of upper airway obstruction and diseases associated with weakness of the respiratory muscles.
- Following the natural history and progression of respiratory and sometimes systemic and neuromuscular diseases.
- Assessment of response to treatment in these conditions.
- Assessment of impairment from respiratory disease in the workplace and in the settings of pulmonary rehabilitation and compensation for occupational disease.
- Pre-operative risk assessment prior to anaesthesia and abdominal or thoracic surgery.

9.

Interpretation

The dynamic lung volumes (eg FEV1 ,FVC) and maximum flows (eg. PEF) of any individual need to be compared with reference values obtained from a reference population using similar test protocols and carefully calibrated instruments.

The presence of ventilatory abnormality can be implied if any of FEV1, FVC, PEF or FEV1/VC are outside the reference range. The inter-relationships of the various measurements are also important diagnostically. For example, a reduction of FEV1 in relation to the forced vital capacity resulting in a low FEV1/FVC% (<70%) constitutes an obstructive ventilatory defect (eg as in asthma and emphysema).

In restrictive ventilatory defects (eg interstitial lung disease, respiratory muscle weakness, and thoracic cage deformities such as kyphoscoliosis), the FEV1 /FEVC% ratio remains normal or high (typically>80%) with a reduction in both FEV1 and FVC. A reduced FVC together with a low FEV1/FVC% ratio may occur as a feature of a mixed ventilatory defect in which a combination of both obstructive and restrictive types coexist. Alternatively it may occur in airflow obstruction as a consequence of airway closure resulting in gas trapping rather than as a result of small lungs. Measurement of other functional indices such as the patient's total lung capacity are necessary to distinguish between these various possibilities.

It is routine practice to quantify the degree of reversibility of an obstructive defect by measuring spirometry before and after the administration of a bronchodilator. Generally, an improvement in FEV1 of 200ml or more infers significant reversibility, if the baseline FEV1 is < 1.5L as does an improvement of > 15% if the FEV1 is > 1.5L. Normal subjects generally exhibit a smaller increase in FEV1 (up to 8% in most studies).

Similarly, the shape of the expiratory flow-volume curve varies between obstructive ventilatory defects where maximal flow rates are diminished and the expiratory curve is scooped out or concave to the X axis, and restrictive diseases where flows may be increased in relation to lung volumes. Reduction of maximal expiratory flow as residual volume is approached is suggestive of obstruction in the peripheral airways. A plateau of inspiratory flow may result from a collapsible extra-thoracic airway whereas inspiratory and expiratory flow are both limited for fixed lesions. Maximal expiratory flow is selectively reduced for collapsible intra-thoracic airway obstruction.

10.

When peak expiratory flow is measured repeatedly and plotted against time (eg. morning and evening values by asthmatic patients) the pattern of the graph can be of great value in identifying particular aspects of the patient's disease. Typical patterns are (i) the "morning dipper" pattern of some asthmatics due to a fall in the early morning hours and (ii) fall in PEF during the week with improvement on weekends and holidays which occurs in occupational asthma. Isolated falls in PEF in relation to specific allergens or trigger factors can help to identify and quantify these for the doctor and patient. A downward trend in PEF and an increase in its variability can identify worsening asthma and can be used by doctor or patient to modify therapy, eg. the patient increases his/her treatment as per asthma action plan cards recently released by the National Asthma Campaign. PEF monitoring is particularly useful in those asthmatics who have poor perception of their own airway calibre for following response to treatment, and to improve self management in conjunction with an action plan. Response to asthma treatment is usually characterised not only by an increase in PEF but also by decrease in its variability.

Normal Values for Spirometry

There are a number of published reference value studies which have generated predictive equations for ventilatory function which take into account gender, height, age and ethnicity. Those produced by the European Community for Coal & Steel Committee (1993) and by Knudson et al (1976) are amongst those used internationally and there are also several sets of Australian normal data - Gibson et al (1979), Crockett (1989) and Hibbert et al (1989). Normal values for PEF may not be as useful to the individual patient as his or her own "personal best". as a target for management of asthma.

Quality Assurance

Equipment standards, calibration and quality control aspects of spirometry are given by the American Thoracic Society (ATS) statement on Standardisation of Spirometry. Guidelines for both spirometry and for infection control in the respiratory laboratory have also been published by the Australian New Zealand Society of Respiratory Society (ANZSRS). For spirometers, at least daily calibration by injecting a known volume of air from a calibrated syringe, at varying speeds (to check linearity) is needed. Flow meter tubes, which may also be used for calibration, are less accurate alternatives. Accuracy of timing devices used for timed volumes (eg FEV₁) should also be assessed.

11.

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3.2 STATIC LUNG VOLUMES

Description:

Static lung volumes and capacities are determined using methods in which airflow does not play a role, so that flow-resistance has no influence. There are four volumes (tidal volume, inspiratory reserve volume, expiratory reserve volume, residual volume (RV)) and four capacities (total lung capacity (TLC). vital capacity (VC), inspiratory capacity, functional residual capacity. VC and its subdivisions may be measured with simple devices, such as spirometers. Because RV is not part of respired volume it (and capacities including it) must be measured by gas dilution or body plethysmography.

12.

Indications

These include the following:

- to evaluate respiratory impairment
- to aid diagnosis by identification of particular disease patterns
- to assess changes with time and/or treatment
- to help interpret other lung function tests
- to help assess fitness for anaesthesia and surgery
- to help assess suitability for lung resection.

Interpretation

At TLC the outward forces generated by inspiratory muscles are balanced by the inward forces generated by elastic recoil of lungs and chest wall. At RV the forces generated by expiratory muscles and inward recoil of lungs are balanced by outward recoil of the chest wall and gas compression of air trapped behind narrowed airways. Hence vital capacity is determined by respiratory muscle strength, elastic properties of the chest wall and lungs, size and patency of airways at low lung volumes, as well as varying with age, height, gender and race. In the absence of gross respiratory muscle weakness the major determinant of TLC is lung elastic recoil. Similarly it is a major determinant of RV both directly and through its effect on airway calibre. Airway narrowing, whether due to loss of elastic support or intrinsic disease is associated with increased RV.

Two broad categories of abnormality in lung volumes are seen in association with respiratory disease: restriction and over inflation. Restriction is seen with decreased compliance of lungs (e.g. pulmonary fibrosis) or chest wall (e.g. kyphoscoliosis). This pattern is, in general, associated with a uniform reduction in TLC, RV and VC. Over inflation is seen with airway narrowing, either extrinsic (due to loss of elastic support) as in emphysema or intrinsic (due to disease directly affecting the airway wall) such as in asthma. These conditions are usually associated with an increase in TLC (particularly emphysema) and a disproportionate increase in RV, so that VC is decreased. Mixed restrictive and obstructive patterns may occur. Respiratory muscle weakness affecting both inspiratory and expiratory muscles may be associated with a decrease in TLC and increase in RV, again decreasing VC.

Normal Values

Many normal values have been published for static lung volume measurements, which vary with age, height, gender and race. A range of commonly used normal values is published in Cotes (1993). Clausen (1982) cites: Boren, Kory and Syner (1966); Goldman and Becklake (1959); Grimby and Soderholm (1963); and Needham, Rogan and McDonald (1954) as the most widely used studies of adult normal values. Zapletal et al (1969) offers normal values for children. Quanjer et al (1989) have comprehensively reviewed paediatric lung function testing.

13.

Specific Quality Assurance

Body Plethysmography:

Daily/twice daily calibration of flow and pressure transducers, check for box leaks (door seal, shutter).

Periodic check of transducers for linearity, signal to noise ratio, drift, phase matching and box leak time constant in the case of a constant volume plethysmograph.

Closed Circuit Helium Gas Dilution:

Check that desiccant and CO₂ absorber are fresh and system leak-free before each use. Periodic check of spirometer volume accuracy, gas analyser linearity.

All results should be checked for their internal consistency with the results of other tests performed on the patient at the time. The patient should be assessed seated upright. He/she should be carefully instructed and observed during the test to ensure that performance of the test is adequate.

Regular (monthly) measurement of multiple normal "laboratory control" subjects is recommended for all these tests.

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14.

3.3 RESPIRATORY MECHANICS

Respiratory mechanics entails examination of the forces involved in the act of breathing. The "active" forces generated by inspiratory muscles are opposed by "passive" forces generated by elastic recoil of the lungs and the chest wall (which increase with increasing volume), resistance to air - and tissue-flow (which increase with increasing flow), and (much less importantly) inertia.

The overall force generating capacity of respiratory muscles is most commonly assessed by measuring the static mouth (or pleural) pressures developed during maximum inspiratory and expiratory efforts at residual volume and total lung capacity respectively. The diaphragm may be assessed independently by measurement of transdiaphragmatic pressures during maximum inspiratory effort.

While elastic recoil of lungs and chest wall and flow-resistance may be measured directly (see below), they are usually inferred: in the case of elastic recoil from measurement of static lung volumes and capacities and in the case of flow-resistance from measurement of maximum expiratory and inspiratory flow rates (see above).

3.3.1 Respiratory Muscle Strength

Definition/Description

Respiratory muscle strength may be assessed globally by measurement of maximum mouth pressures. The strength of the diaphragm may be assessed by measurement of maximum transdiaphragmatic pressure (P_{dimax}).

(a) Maximum inspiratory and expiratory mouth pressures

These measurements reflect the force generating capacity of inspiratory and expiratory muscles respectively. Maximum inspiratory pressure (MIP) is measured during maximum inspiratory effort against an occlusion at RV (where mechanical advantage of inspiratory muscles is greatest) or FRC. Maximum expiratory pressure (MEP) is measured during maximum expiratory effort at TLC (where mechanical advantage of expiratory muscles is greatest). A small leak is included in the circuit to assist in preventing large transients due to use of buccal muscles.

(b) Maximum transdiaphragmatic pressure (P_{dimax})

Various manoeuvres have been described to assess P_{dimax} . These include measurement during maximum inspiratory effort to TLC and against an occlusion at FRC and RV; during maximum inspiratory and expulsive efforts, and during maximal sniffs. In favour of the latter manoeuvre is the ease with which it is taught to naive subjects, its reproducibility, and the relatively well defined range of normal values.

15.

Indications/Interpretation

To evaluate the degree of suspected or known respiratory muscle weakness and its changes with time and/or treatment.

Normal Values

- | | |
|---------------------|-------------------------------------|
| (a) MIP, MEP: | Black and Hyatt, 1969, Bruschi 1992 |
| (b) Pdimax: at TLC: | Newsom-Davis et al, 1976 |
| at FRC | Lisboa et al, 1986 |
| with sniffs | Miller et al, 1985. |

Specific Quality Assurance

Accuracy and linearity of the pressure gauge or transducer used should be assessed at regular intervals (at least quarterly), and whenever erroneous measurements are suspected.

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3.3.2 Elastic Recoil of Lungs and Chest Wall

Definition/Description

The elastic properties of the lung and chest wall are defined by the relationship between change in lung volume and the associated changes in transpulmonary and transthoracic pressure gradients respectively. These pressures are usually measured under "static" conditions produced by momentary occlusion of the airway by a shutter, closed at intervals during slow expiration from TLC. Interruption of airflow ensures that the measured pressure gradients only reflect elastic recoil forces and not those associated with airflow (ie. resistance). To measure chest wall elasticity the chest wall musculature must be relaxed.

16.

The volume pressure relationship of the lung is curvilinear. The whole curve may be examined between TLC and FRC. Both its shape and position are important in evaluating the elastic properties of the lung. A simple estimate of lung elasticity, lung compliance, is obtained by measuring the slope of the linear portion of the curve - the litre above FRC. This measure may be normalised for variations in lung size by dividing it by FRC - specific compliance. A more precise description of compliance is given by the exponent K of exponential treatment of the pressure -volume data. Total respiratory compliance may be calculated from lung and chest wall compliance ($1/\text{compliance (total)} = 1/\text{compliance (lung)} + 1/\text{compliance (chest)}$). A crude estimate may be obtained in mechanically ventilated relaxed patients by dividing tidal volume by inspiratory pressure.

Indications/Interpretation

- To evaluate interstitial lung disease and emphysema
- To distinguish intrinsic from extrinsic airway narrowing.

Interpolation of maximum flow-volume and volume-pressure relationships allows examination of maximum flow at a range of transpulmonary pressures: where flow rates are reduced but normal relative to transpulmonary pressure the cause of airway narrowing is likely to be extrinsic eg. emphysema. Low flow rates relative to transpulmonary pressure suggest intrinsic airway narrowing.

Normal Values

Begin et al (1975), Colebatch (1979)

Specific Quality Assurance

Prior to each measurement: calibration of flow, volume and pressure transducers; check integrity of oesophageal balloon. It is important to standardise the patient's "volume history" prior to each measurement. Regular (monthly) measurement of normal "laboratory control" subjects is suggested for all these tests. Periodic check of transducers for linearity, signal to noise ratio, drift.

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17.

3.3.3 Respiratory Resistances

Description

The upper airway is a major contributor to total airway resistance, particularly with nasal breathing and/or during sleep, when loss of muscle tone can precipitate partial or complete obstruction in predisposed individuals.

While measurements of nasal resistance are important in the investigation of nasal obstructive lesions, measurements of lung resistance are usually made with the patient breathing through the mouth, removing the influence of the nasal airway. During quiet breathing (awake) the mouth, pharynx, larynx and trachea account for 20 - 30% of total airway resistance. The major sites of remaining airway resistance are the lobar, segmental and subsegmental airways, up to about the 7th generation. Because of their high total cross-sectional area, the numerous small (< 2 mm diameter) peripheral airways normally contribute less than 20% of total airway resistance. Lung resistance is the sum of the airway resistance (>90%) and tissue resistance (<10%). These are usually measured at the low flow rates associated with tidal breathing. As airways resistance varies with lung volume it is essential that it is assessed at a constant and reproducible lung volume. Although its reciprocal, conductance, is linearly related to lung volume (except near TLC), the force distending airways approximates the elastic recoil pressure of the lung. Thus conductance is best normalised by relating it to the elastic recoil at the same volume. The ratio of conductance to lung volume (specific airway conductance) can be used to normalise the measurement when comparing measurements under different conditions in the same subject.

Assuming laminar flow: resistance (in cm H₂O)/L/s) = pressure gradient (in cm H₂O) divided by flow (in L/s). In measuring airway resistance the relevant pressure gradient is that between mouth and alveoli: in measuring total lung resistance it is that between mouth and pleural space. Several methods have been developed to measure these pressure gradients. Alveolar pressure, which cannot be measured directly, can be derived by using the "body plethysmograph" or "interrupter" methods. Measurement of total lung resistance may be made by simultaneous recording of flow, mouth to intrapleural pressure gradient (oesophageal balloon), and lung volume. The component of pressure gradient change due to change in lung volume (ie. elastic recoil) is then subtracted ("subtraction" method). Total respiratory resistance (lung and chest wall) may be measured by the "forced oscillation" method.

18.

Indications/Interpretation

- To investigate the cause of decreased maximum expiratory flow rates.
- To determine the cause of airway narrowing: airway conductance is normal relative to elastic recoil pressure in airflow obstruction due to extrinsic causes. This illustrates the point that resistance and lung elastic recoil are interdependent because of the importance of elastic support in maintaining the patency of intrapulmonary airways.

Normal Values

Dubois et al. (1956), Briscoe and Dubois (1958).

Specific Quality Assurance

Prior to each measurement: calibration of flow, volume and pressure transducers; check integrity of oesophageal balloon where applicable. Check body plethysmograph, as above. Periodic check of transducers for linearity, signal to noise ratio, drift, phase matching.

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3.4 BRONCHIAL PROVOCATION

Bronchial provocation testing identifies and characterises airway hyper-responsiveness. Bronchial hyper-responsiveness (BHR) refers to an exaggerated response to a bronchoconstrictor and is reflected by an increased sensitivity to the stimulus. The bronchoconstrictive stimuli used are pharmacological agents (histamine, methacholine), physical stimuli (non-isotonic aerosols, cold/dry air, exercise) and specific sensitising agents (allergens, occupational sensitisers) Provocation tests with each of the various bronchoconstrictor stimuli require distinct laboratory protocols. In addition a number of different protocols exist for the various stimuli. Interested readers should consult the literature for a description of standardised protocols, analysis of the data and interpretation of the results.

19.

Indications

- To diagnose or confirm a diagnosis of BHR.
- To document severity of BHR
- To follow changes in BHR after therapeutic intervention or aggravation of symptoms.
- To exclude asthma in patients with chronic cough.
- To determine who is at risk in the workplace or during recreational activities.
- To establish a control or baseline prior to environmental or occupational exposure.

Provocation tests are useful in the clinical diagnosis of patients with variable airways obstruction. The pharmacological tests using histamine and methocholine are particularly suitable for the exclusion of asthma because of high sensitivity and high negative predictive value. However pharmacological tests are less useful to confirm the diagnosis due to their moderate specificity and relatively low positive predictive value. Careful selection of multiple cut-off values can optimise the positive and negative predictive values of the pharmacological tests, even though this introduces a considerable intermediate area of inconclusive test results. Physical stimuli such as isocapnic hyperventilation or hypertonic saline inhalation may be more useful to confirm a diagnosis of asthma because of their high specificity. Unfortunately physical stimuli have relatively low sensitivity which results in a significant number of mild asthmatics having a negative test result. Additionally, physical stimuli are useful in specific circumstances such as to confirm a diagnosis of exercise induced asthma or to assess patients with a history of asthma who wish to SCUBA dive.

Since mild bronchial hyper-responsiveness is also associated with COPD, a positive test for pharmacological challenge particularly cannot be used in the differential diagnosis with asthma. Therefore, in the presence of airways obstruction the tests are less discriminating. Bronchial hyper reactivity also occurs following upper respiratory infections and atopic non asthmatics and those with a past history of asthma. Thus it cannot be used alone to diagnose asthma.

Normal Values and Interpretation

Spirometry performed before and after the bronchoconstrictor stimulus is most commonly used to quantify response. A positive test is characterised by a specific dose or level of stimulant at a defined fall in FEV1. usually 20%.

20.

Pharmacological Tests

A positive test is defined by a fall in FEV1 of 10% or more in response to the inhalation of diluent or a decrease in FEV1 from diluent FEV1 value of 20% or more in response to inhalation of bronchoconstrictor . Bronchial provocation tests are commonly performed according to specific protocols, either by cumulative dose measuring PD₂₀ (Yan et al) or by the longer method measuring PC (Cockcroft et al). A PC₂₀ < 0.25 mg/ml (PD₂₀< 0.1 µmol) is a severe response, a PC₂₀ 0.25-2.0mg/ml (PD₂₀ 0.1-0.8 µmol) a moderate response and a PC₂₀ 2.0-8.0 mg/ml (PD₂₀, 0.8-8.0 µmol) is a mild response.

Physical Tests

Non-isotonic aerosols: a positive test is defined by a fall in FEV1 of 15% or more. A PD₁₅ < 2.0 ml defines a severe response, a PD₁₅ 2.1 - 6.0 ml is a moderate response while a mild response is a PD₁₅ 6.1 - 20.0 ml.

Cold/Dry Air: a positive test is a fall in FEV1 of at least 10%. For adults, a severe response is a PV₁₀ <40 L/min, a moderate response is a PV₁₀ 40-80 L/min and mild is PV₁₀ > 80 L/min. In children responses are measured in terms of VE as a % of MVV.

Exercise: a fall in FEV1 of 10% or more indicates a positive result to the provocation. A severe response is a 50% or more fall in FEV1, a moderate response 25 - 50%, and a mild response is a fall in FEV1 10-25%. If the patient is on steroids however, a fall of > 25% would be regarded as severe.

Quality Assurance

For bronchial provocation to be reliable both the stimulus delivered and the measurement of the response must be accurate. Consequently, bronchial provocation testing for clinical purposes should be performed using standardised techniques in an accredited respiratory function laboratory by trained and experienced staff.

Safety

It is very important to follow the safety guidelines for the tests particularly with respect to the starting dose of provoking agent. "Omitting " doses or increasing the initial intensity of the stimulus is not advised. Emergency resuscitation equipment and medical assistance should be readily available whenever bronchial provocation tests are performed.

21.

References

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22.

4. TESTS OF GAS EXCHANGE

4.1 BLOOD GAS ANALYSIS

Description

Blood gas analysis, particularly of arterial blood, provides essential information about the state of oxygenation, acid base balance and severity of respiratory failure. Analysis of blood from sites other than the systemic arteries, particularly mixed venous blood from the pulmonary artery, is occasionally indicated. However, further comment will refer to the sampling and analysis of systemic arterial blood which provides the most usually required information about the degree of respiratory failure and oxygen delivery to the tissues.

Blood gas analysers measure oxygen partial pressure (PaO₂), carbon dioxide partial pressure (PaCO₂) and hydrogen ion activity (pH) in arterial blood and also calculate indices of bicarbonate concentration, base excess, and oxygen saturation. The very low oxygen stores of the body and the critical importance of acid base balance to organ function underpin the importance of these measurements. It is important to appreciate that the calculation of arterial oxygen saturation in this way assumes a normal oxyhaemoglobin dissociation curve and the absence of abnormal haemoglobins and that this may not reflect the in vivo circumstances.

Proper attention must be paid to patient comfort when sampling blood from systemic arteries. When feasible, a small amount of local anaesthetic should be infiltrated before puncturing the artery and a > 23 gauge needle should be used to minimise trauma to the arterial wall. Alleviation of discomfort also helps ensure a steady state of ventilation and cardiac output, essential to the interpretation of derived indices such as the alveolar - arterial oxygen gradient and dead space/tidal volume ratio. An indwelling cannula should be inserted by an experienced operator when multiple sampling is required.

Single samples should be taken from the radial artery after performing a modified Allen test to ensure adequate collateral circulation of the hand. The sampler must wear gloves, ensure high pressure occlusion of the puncture site and dispose of the needle using a single hand technique after the procedure. The syringe should be immediately capped after expulsion of any bubbles, transported to the laboratory and analysed within 10-20 minutes. Transport in ice is not necessary in this time frame unless the white cell count is very high. Extreme white cell counts encountered in leukaemic patients will cause a spuriously low PaO₂ due to ongoing metabolism even when the blood is chilled. Blood taken during supplemental oxygen breathing where the expected PaO₂ will be > 100 mmHg must be analysed immediately. A 5 ml plastic syringe with only the dead space and needle filled with 1,000 u/ml Heparin may be used and 2-4 ml of blood should be taken to adequately dilute the Heparin and avoid a pH effect. Manufacturer's instructions should be followed for other systems using lyophilised Heparin. A record of the inspired oxygen concentration should be made at the time of sampling.

23.

Personnel taking arterial blood gas samples must be adequately trained in the techniques and regular review of the skills and procedures needs to be undertaken in hospitals and laboratories, preferably by the Director of the respiratory function laboratory or by respiratory specialist staff.

Blood gas measurements which are part of larger respiratory function studies should be formally interpreted by the respiratory function laboratory. Isolated measurements performed for the purposes of immediate clinical management will usually be interpreted by the attending clinician. An appropriately experienced physician should be available to assist in this interpretation if necessary.

Indications

- arterial blood gas measurements are crucial to the management of the majority of acute respiratory disorders requiring hospital admission. Most patients in intensive care units and all requiring mechanical ventilation will need regular monitoring of blood gases.
- baseline arterial blood gas measurements are advisable for all patients with cardiorespiratory disorders before any surgical or endoscopic procedure and the results will determine the need for further monitoring with blood gases or pulse oximetry or both
- All cardiopulmonary surgical procedures require careful monitoring of blood gas changes.
- Blood gas analysis from time to time is essential for the management of chronic respiratory failure. The less invasive pulse oximetry will provide adequate information about oxygen status alone and is particularly valuable during sleep and exercise studies. However, it is important to obtain extra information from blood gas measurements on occasions particularly to assess PaCO₂.
- Assessment for domiciliary oxygen therapy.

Quality Assurance

Modern blood gas analysers are programmed with self calibrating routines, using standard gases and solutions, which are reasonable robust and reliable. However, experienced scientific staff who are alert to the indications of malfunction and incorrect sample placement must maintain these analysers. Use of standard vials of reference solutions at least daily is standard practice. Checking the electrodes with blood tonometered to a range of oxygen and carbon dioxide tensions may be employed from time to time. The occasional user of these machines must be confident that they are being kept in good working order. There is no place for a blood gas analyser “ on the ward “ or “ in the unit “ where there is no daily supervision by knowledgeable technical staff. Participation in externally managed quality assurance programs is strongly recommended and NATA accreditation is advised.

24.

References

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4.2 CO DIFFUSING CAPACITY (TRANSFER FACTOR)

Description

The carbon monoxide diffusing capacity (DLCO) or transfer factor of the lung is a measurement of the rate of transfer of CO from inspired gas to pulmonary capillary blood. It is used primarily to ascertain the health of the alveolar-capillary membrane, or gas exchange surface of the lung, and in specific circumstances (see below) it is helpful as a diagnostic aid or to follow disease progression. The transfer of CO from the inspired gas to capillary blood is a relatively complex process the rate of transfer usually being limited by the properties of the alveolar-capillary membrane and the capillary blood “ sink “ on the other side.

It is important to appreciate that the DLCO is not a measure of gas exchange efficiency hence the term gas transfer or diffusing capacity. Although it measures the integrity and functioning of the diffusing surface of the lung, the uptake of oxygen and elimination of carbon dioxide are not limited by the diffusing capacity of the alveolar-capillary membrane except where the membrane is markedly thickened (in advanced interstitial pulmonary fibrosis for example) and red cell transit time is reduced during exercise. Abnormalities in DLCO and blood gases are often unrelated. Hence in asthma, poor gas exchange as measured by arterial blood gases is often present with a high normal DLCO; while near normal blood gases at rest will coexist with a low DLCO in emphysema.

25.

In addition to the diffusion of gas across the alveolar-capillary membrane, CO- transfer involves bulk flow of gas to the alveoli, gas mixing within the terminal air spaces, and chemical reaction with blood constituents largely haemoglobin. In measuring and calculating the DLCO it is customary to adjust or control for these other influences. The KCO is the DLCO per litre volume of distribution of the inspirate during a single breath test and is a commonly used clinical index as it “corrects” for lung volume. The units of DLCO are ml/min/mmHg CO driving pressure while the units of KCO are ml/min/mmHg/litre lung volume. Different methods for measuring DLCO have been published. The single breath technique has been widely adopted and is now the preferred method. There are agreed standards for performing the single breath test ^{1,2} and there are satisfactory normal values.

Indications

Measurement of DLCO may be indicated in the following circumstances:

- The diagnostic evaluation and follow-up of patients with diffuse interstitial lung diseases eg. idiopathic pulmonary fibrosis, pneumoconiosis, drug induced lung disease,
- The evaluation of patients suspected of having emphysema.
- The evaluation of patients with connective tissue diseases such as rheumatoid arthritis and scleroderma in whom diffuse pulmonary involvement is suspected.
- The diagnostic evaluation and follow-up of patients with pulmonary vascular disease (eg primary pulmonary hypertension, recurrent pulmonary thromboembolism, hepatopulmonary syndrome).
- The baseline evaluation and follow-up of patients treated with agents known to have a high risk of diffuse lung damage (eg bleomycin, amiodarone), and in whom this information is likely to lead to the early detection of lung toxicity and a change in therapy.
- The diagnostic evaluation and follow-up of patients with haemorrhagic lung disorders.

The DLCO is not indicated in the routine assessment of patients with asthma nor as a screening test (eg pre-vocationally) for lung disease.

Interpretation

Tests within a single measurement session should be accepted as reliable if at least two results are obtained that are within 10% or 3 ml CO (STPD)/min/mmHg of the average DLCO. The mean of the acceptable test results is usually reported. The DLCO is significantly influenced by the size of the gas exchange surface (ie alveolar volume) at the time of the measurement and by perturbations in blood haemoglobin concentration (eg anaemia). The measurement can also be influenced by prior CO exposure (eg recent smoking). The test report should include a DLCO value that is corrected for alveolar volume, the latter being measured by inert tracer gas during the performance of the test. Corrections for haemoglobin concentration^{1,2} should be included, if not routinely, then at least when an abnormal haemoglobin concentration is known or suspected. Patients should be asked to refrain from smoking 24 hr before testing, and a correction should be made for CO back pressure for recent or heavy smoking. In interpreting changes in DLCO in individual patients over time or following treatment it should be borne in mind that a spontaneous variability of approximately 10% has been reported in normal subjects.

Normal Values

The selection of appropriate reference equations for DLCO has been acknowledged to be problematic. A wide selection of normative values and regression equations have been published. It is recommended that each laboratory select reference equations that best suit the methods used by the laboratory and the population to be tested. The laboratory should formally compare measured with predicted values in at least 15 normal subjects of each sex to confirm the appropriateness of the chosen reference equations.

Quality Assurance

Recommendations on the proper performance of the DLCO test, calibration of equipment and infection control measures are available in previously published documents. It is emphasised that the calculation of the DLCO requires several separate measurements (eg inspired and expired gas concentrations, breath holding time) and incorporates a number of computational steps. The risk of technical/ measurement error is therefore relatively high and great care needs to be exercised in the quality control aspects of testing to minimise this.

27.

References

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- 3. American Assoc. Of Respiratory Care Clinical Practice Guidelines: Single-breath carbon monoxide diffusing capacity. Respir Care 1993; 38(5): 495-521

28.

5. ASSESSMENT OF RESPIRATORY CONTROL

Description

Ventilatory drive is influenced by a variety of factors including conscious state, volition, emotion, arterial pH, PCO₂ and PO₂ (via chemoreceptors), mechanoreceptors in the chest wall and lungs, and irritant receptors in the airways. Furthermore the translation of ventilatory drive into ventilation is a function of the integrity of neural pathways, strength and efficiency of respiratory muscles, and magnitude of the mechanical loads with which those muscles cope, which increase with restrictive or obstructive respiratory diseases.

All these factors must be considered in assessing control of breathing and in interpreting specific tests of it. The most commonly performed of these tests are measurements of the ventilatory responses to hypercapnia and hypoxia. Hypercapnic responses assess the relationship between ventilatory output and arterial CO₂ concentration (usually estimated from end-tidal PCO₂) in the presence of normoxia. Hypoxic responses assess the relationship between ventilatory output and arterial O₂ concentration (usually estimated from pulse oximetry) in the presence of a stable arterial PCO₂. While ventilatory output from both tests is often assessed by minute ventilation, measurement of inspiratory occlusion pressure at 100 msec (P_{0.1}) is less affected by increased mechanical loading associated with restrictive or obstructive respiratory diseases.

The ventilatory response to hypercapnia is most commonly assessed using the rebreathing method of Read. This method involves rebreathing from a circuit of relatively low volume with an initial circuit PCO₂ close to that of mixed venous blood to ensure that a constant relationship is established between end tidal PCO₂ and cerebral medullary PCO₂, unaltered by and therefore independent of ventilation. Hence the rebreathing bag is usually filled with approximately 6 litres of a mixture containing 5 to 7% CO₂ with the remainder O₂ (to eliminate hypoxic drive). The test usually continues until limited by dyspnoea, by achievement of an end-tidal CO₂ concentration of 9%, or until 4 minutes has elapsed.

The ventilatory responses to hypoxia reflects drive from peripheral chemoreceptors. These are also responsive to hypercapnia and the effects are interactive. Furthermore, while hypoxaemia stimulates ventilation peripherally, the effects “ roll-off “ with prolonged stimulation, in part because of central hypoxic depression. Hence hypoxic responsiveness is assessed under isocapnic conditions, with hypoxaemia either induced by transient introduction of a hypoxic gas mixture or by rebreathing expired gas, with CO₂ absorption controlled to maintain end-tidal CO₂ constant.

29.

Indications

- Assessment of hypoventilation not explained by respiratory disease associated with impairment of ventilatory capacity or gas exchange.
- Assessment of respiratory sleep disorders associated with hypoventilation.

Interpretation

There is considerable variability in the normal values for these tests. Some of the variability is attributable to variation in ventilatory capacity. Hypoxic responses vary with the PCO₂ level at which the measurement is made: these should be recorded. These, and other potential sources of variability should be carefully considered in interpreting the results.

Normal Values

Hypercapnic Response: Read (1967), Irsigler (1976)

Hypoxic Response: Rebuck and Campbell (1974), Rebuck and Woodley (1975)

Specific Quality Assurance

Prior to each test:

- Calibration and linearity check of gas analysers, pneumotachograph
- Preparation of gas mixtures, where applicable
- Check for circuit leaks, operation of valves, oximeter
- Check availability of emergency oxygen and resuscitation equipment.

As with other pulmonary function tests it is recommended that the tests be performed periodically on normal individuals who act as laboratory standard controls.

References

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30.

6. EXERCISE ASSESSMENT

Description

Exercise testing involves stressing the systems involved in exercise to ascertain the peak performance and the normalcy compared with a reference population, to provide a reference for change of a condition with or without treatment or to provide a trigger to identify an abnormality.

An incremental protocol, with gradually increasing work levels to a symptom limited maximum, allows the inter-relation of the measured variables to be observed throughout the normal work range, eg, Jones. Steady state protocols are used less frequently, although they can provide more detailed information at the chosen work level.

Cycle ergometers are preferred to treadmills because of their more accurate measurement of the workload. Continuous measurements are made of heart rate, oxygen saturation, ventilation oxygen uptake and carbon dioxide production. Blood pressure is ideally measured each minute. 12-lead ECGs are performed before the test, at maximum exercise and during the recovery period, and continuous ECG monitoring allows recognition of arrhythmias or ischaemia. The space and facilities for advanced life support should be available and the test must be continually monitored by a trained medical practitioner, as well as a scientist also trained in cardio-pulmonary resuscitation.

Description

Jones multistage progressive test to symptom limited maximum on cycle ergometer whilst monitoring workload, heart rate, BP, oxygen saturation, ventilation, oxygen uptake and carbon dioxide production and 12 lead ECG monitor.

Indications

- Investigation of breathlessness on exertion, to determine if there is cardio-respiratory dysfunction present.
- Quantification of impairment of exercise capacity.
- Diagnosis of exercise induced asthma. (special protocol required)
- Assessment of disease progression.
- Assessment of response to treatment.
- Pre-operative assessment for lung resection.

31.

Interpretation

- It is not usually possible to define a definite disease process from measurements of exercise physiology except for exercise-induced asthma, cardiac ischaemia or arrhythmia.
- An indication is required that a maximum test has been performed, such as the patient reaching their maximum predicted HR, their anaerobic threshold, a ventilatory limitation, a severe hypoxaemia or some other definite exercise limiting symptom.
- Knowledge of Hb level is also required.

Workload

- A maximum workload of < predicted can be related to the predicted value to quantify impairment. This can usually be expressed as a percentage of predicted
- VO_2 max is a key indication of functional aerobic capacity

Cardiovascular Change:

- ECG - >2 mm ST depression indicates myocardial ischaemia. Arrhythmias may also be identified.
- Blood Pressure- A BP which does not rise or falls during exercise suggests LV dysfunction.

Heart Rate

The heart rate for any given workload or VO_2 can suggest a reduced stroke volume if it is elevated or an increased stroke volume (fitness) if it is decreased. Obviously beta blockade or nodal disease can also influence heart rate as can deconditioning.

Ventilation

The ventilation may be the limiting factor to exercise in some elite athletes or in patients with abnormalities of gas exchange, either due to lung problems or pulmonary congestion due to cardiac dysfunction but some ventilatory reserve is normally present at peak exercise.

Oxygen Saturation

This can provide an estimate of gas exchange during exercise but can underestimate this if alveolar hyperventilation or a right shift on Hb O_2 dissociation curve is not recognised.

32.

Quality Assurance

1. Use of equipment which met ATS specifications and is calibrated regularly.
2. Examination of a plot of oxygen uptake vs workload, as values falling off the predicted line indicate either oxygen uptake or energy expenditure not measured by the cycle (eg. obese subjects lifting their legs) or equipment malfunction.
3. Regular checks for system leaks.
4. Regular performance of exercise tests by known normal subjects.
5. It is essential to ensure that physicians supervising tests and scientists performing them are suitably trained and experienced.

Cost Benefit

Early confirmation that breathlessness on exertion is not caused by any cardiopulmonary dysfunction can rapidly direct attention at more likely causes of the symptom and avoid unnecessary tests.

Similarly ascertaining that a disease process is improving, either spontaneously or with treatment, can save unnecessary investigation.

Quantification of disability also allows for an objective approach to the awarding of compensation.

References

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33.

7. GENERAL ASSURANCE CONSIDERATIONS

A well designed quality assurance programme is essential to provide accurate, clinically relevant and timely results of lung function tests. This section describes the general components of a quality assurance programme recommended for respiratory function laboratories.

7.1. PROCEDURE MANUAL

A comprehensive procedure manual should be available which documents the specific methodology for each test the laboratory performs. The manual should be compiled by the laboratory staff. The manual should list for each test equipment and supplies, detailed directions on calibration, quality control test performance, calculations, normal values and interpretation and infection control, troubleshooting and patient safety plus relevant publications and bibliography.

The manual should be reviewed and, if necessary, updated continuously with changes approved by the medical and technical directors of the laboratory.

7.2. PREVENTATIVE MAINTENANCE

Equipment maintenance should be performed according to the manufacturer's schedule and a maintenance log should be established.

Electrical safety checks should be conducted on each item of equipment at scheduled intervals.

7.3. CALIBRATION AND QUALITY CONTROL

Calibration should be performed with standardised instruments on a regular basis.

Following calibration quality control procedures should be performed to determine the deviation of the observed value from the target value. If the results of control testing are outside defined limits corrective action must be taken. Selected intervals should reflect the inherent stability of devices and the relative importance of inaccurate measurement against time and cost implications. All calibrations results should be recorded.

34.

7. 4. PERFORMANCE ASSURANCE TESTING

A log should be established showing test results for at least 2 healthy normal subjects. These subjects should be drawn from the staff of the laboratory. The measurements should be repeated at regular, preferably monthly, intervals or whenever questions arise regarding the accuracy of the test results. When sufficient data is available any result which consistently deviates from the expected result for each subject should result in a complete equipment review to remedy potential problems.

Despite progress towards standardisation of methodology and instrumentation, significant measurement differences are consistently identified between laboratories. For this reason, inter-laboratory comparison should be performed whenever possible and at least annually, by testing the laboratory "normals" at other laboratories using the same or similar equipment and methods.

The reference value equations used in the laboratory should be assessed by testing a number of non-smoking healthy normals and comparing the results with predicted results from reference value equations.

7. 5. STAFFING

For most respiratory function tests the staff member performing the test is the single most important factor in obtaining adequate and reliable results. Staff should therefore be experienced, well trained and motivated. Continuing education is essential for all staff.

Guidelines for respiratory function laboratory personnel have been published. The medical director must have a broad interest and expertise in respiratory pathophysiology. The chief laboratory scientist and preferably all the scientific staff of the laboratory should obtain credentials based on examination by the relevant professional organisation (ANZSRS).

7. 6. ACCREDITATION

All clinical respiratory function laboratories should gain accreditation from the relevant professional organisation (TSANZ).

35.

References

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- Guidelines for infection control in a Respiratory Function Laboratory - Crockett A, Grimmond TSANZ 1993.

8. COST BENEFIT CONSIDERATIONS

Medical training focuses on the benefits and outcomes of medical and surgical treatment. Whilst this is the prime objective of professional activity clinicians are increasingly being made aware of, and in the future may be held accountable for, the costs of any special investigations ordered. This approach is reasonable and is likely to become more widespread in a future of austerity and reduction in resource allocation. cost benefit assessments will thus become a significant factor in the decision whether to order respiratory function tests and which tests to order. Respiratory function testing may assist the clinician in the assessment of patients with respiratory disorders. All tests have potential benefits and costs which the clinicians should balance before ordering them. As a general rule simple, cheap, highly discriminate tests are preferred to costly tests which provide limited information. Tests ordered on the off-chance that useful information may be found should be avoided. simple tests (eg spirometry) and more complex investigations (eg diffusing capacity, bronchial provocation) are commonly performed to:

1. determine the physiological pattern on abnormality eg obstructive, restrictive.
2. evaluate response to treatment.
3. follow the natural history of the disease process.
4. determine a specific diagnosis, eg specific provocation tests.

Benefits of tests are relatively obvious:

- (i) characterisation and quantification of the physiological deficit (eg airflow limitation in an asthmatic patient).
- (ii) determination of the efficacy of treatment.
- (iii) following the natural history of the disorder.
- (iv) identification of prognostic information.
- (v) prediction of operative risk.

37.

Costs of tests are both financial and medical

- (i) financial costs
 - to the patient (direct and out-of-pocket).
 - to the health care system (Medicare, Health funds, Insurance companies, etc).

- (ii) Medical risks
 - complications of the test.
 - reactions to tests drugs (eg histamine).
 - physical injury, eg with arterial puncture.
transmission of infection to medical and scientific staff (direct spread by airborne aerosol) and other patients (inadequate sterilisation of equipment).
 - discomfort to patient caused by the test, eg dyspnoea during exercise.

- (iii) Technical Costs
 - Poor performance of the test rendering it useless or misleading for interpretative purpose.
 - Unrecognised poor performance leading to misleading results.
 - Time spent by patient in attending the laboratory.

There are other factors that need to be considered when ordering respiratory function tests apart from costs and benefits.

- (i) Is the test being done for sound clinical reasons and not purely for academic purpose or for the purposes of direct financial gain?

- (ii) Will the test result in any diagnostic gain or therapeutic change?

- (iii) Can a simpler, cheaper test with lesser costs be used as an alternative eg, peak expiratory flow rate measurement in place of spirometry.

38.

The frequency at which respiratory function tests should be repeated should be carefully considered. In many situations repeated testing does not contribute in any material way to patient management. The frequency of testing needs to be determined on clinical grounds and must be medically justifiable. Thus monthly complex lung function testing of patients with stable or relatively stable chronic airflow limitation or interstitial disease is unlikely to be helpful and is inappropriate. Conversely in patients with rapidly deteriorating disease regular testing is sensible and justifiable. However, if regular and repeated testing is necessary, it is sensible to consider whether a simpler less expensive test would be just as useful (eg. peak flow monitoring in the routine management of asthmatic patients.).

In summary, respiratory function testing is recognised as a part of the routine management of patients presenting with lung disease. Testing of these patients needs to be medically justifiable and appropriately determined to achieve the desired assessment at the cheapest cost (not just financial) with the least risk to the patient and staff. Appropriately applied, it can play a useful and very important role in the diagnosis and management of patients with respiratory disease.

9. FUTURE DIRECTIONS

This document attempts to provide information about the respiratory function tests commonly used in the late 1990's in clinical practice relating to respiratory disease. At the present time we remain in need of a great deal of further information on the sensitivity, specificity and positive and negative predictive value of these tests in specific disease states and clinical situations. In the area of bronchial provocation testing for example, much is already known about its diagnostic value in asthma. For other tests however, lack of knowledge of these parameters leads to the uncertain usage of functional evaluation or even its omission from clinical practice.

Other reasons for the exclusion of respiratory function tests from clinical decision making relate to their inconvenience or invasiveness. For example we have been unsure about the predictive clinical value of routine pulmonary artery pressure measurements in the evaluation of likelihood of response to long term domiciliary oxygen therapy in hypoxic COPD or in the prediction of adverse outcomes from lung resection. Although we know that pulmonary hypertension is adversely predictive of outcome in COPD, the invasiveness and potentially serious complications of this test have limited use of direct PAP measurement to research studies. Now that echocardiographic pulmonary artery pressure measurements are available and are easily and non-invasively obtainable in most subjects, the clinical usefulness of such measurements in these particular clinical settings needs to be formally investigated so that evidence-based decisions can be made about whether or not to include such tests in the clinical evaluation of patients.

It is important in describing the current incomplete state of our knowledge of the clinical value of respiratory function tests to foster advancement of current practice. We should be encouraging:-

- i) exploration of the interpretation, application and limitation of commonly used tests.
- ii) the wider adoption and further evaluation of tests for which there exists reasonable evidence of clinical utility.
- iii) the development of newer tests which if available would have clinical utility. Although it is sensible to adopt a "reasonable best practice" approach for clinical use of respiratory function tests, ongoing research needs to be actively pursued. This is required to further refine our use of the current widely used tests, to define the role of similar tests not in widespread clinical use (eg measurements of ventilatory drive) and to develop new tests with greater sensitivity and specificity for clinical diagnosis than those in current use and to compare them formally with those in currently accepted practice.

40.

We also need to refine respiratory function tests for epidemiological and population studies. Early detection of specific lung disorders by functional evaluation in screening programs is another field for further research. For all these reasons respiratory function testing should be considered as an area of continuing development from which substantial additional clinical and public health gains are yet to be harvested.