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**A Brief Guide to Spirometry
using Vitalograph Pneumotrac**

Spirometry is a key pulmonary function test. Results from spirometry tests give objective measures of lung function and can be used for the assessment, diagnosis and management of asthma, COPD, cystic fibrosis and other respiratory and systemic diseases.

Spirometry is dependent upon the effort given by the subject. The test is a forced manoeuvre and therefore it requires maximum effort to be given by the patient.

To get the best out of the patient when conducting spirometry you must always:

- **Prepare** the equipment ready for spirometry
- **Explain** to your patient how to perform the manoeuvre
- **Demonstrate** to the patient how to perform the manoeuvre
- **Coach** the patient through the manoeuvre
- **Review** the manoeuvre and provide feedback to the patient

To simplify spirometry, you should consider it as a 3 step process:

- **Step 1:** Pre-test
- **Step 2:** Test
- **Step 3:** Post-test

The **pre-test** includes equipment preparation, patient introduction and patient instruction. The **test** is the actual performance of the spirometry manoeuvres. The **post-test** is the review of the test for acceptability and session repeatability.

This document provides guidance on all three steps including checking results for acceptability, repeatability and error recognition. Also included is a glossary of abbreviations, definitions and references supporting spirometry testing and standards. All guidance provided for spirometry is given in accordance with ATS/ERS 2005 Standardisation of Spirometry Guidelines.

For further information refer to:

Miller et al. (2005) Standardisation of Spirometry, Eur Respir J, 26, 319-338.

Abbreviations			
ATS	American Thoracic Society	L	Litres
BVF	Bacterial Viral Filter™	LABA	Long Acting Beta Agonist
CRA	Clinical Research Associate/ Site Monitor	LAMA	Long Acting Muscarinic Antagonist
COPD	Chronic Obstructive Pulmonary Disease	PEF	Peak Expiratory Flow
ERS	European Respiratory Society	PFT	Pulmonary Function Test
FEV1	Forced Expiratory Volume after 1 second	QA	Quality Assurance
FEV6	Forced Expiratory Volume after 6 seconds	QC	Quality Control
FVC	Forced Vital Capacity	SABA	Short Acting Beta Agonist
IT	Information Technology	TLC	Total Lung Capacity

Definition	
Acceptability criteria	<ol style="list-style-type: none"> 1. Good start of test, without hesitation (extrapolation volume must be < 5% of FVC or 0.15L whichever is greater) 2. No cough detected in the first second of expiration 3. 1 second volume plateau 4. Minimum of 6 second exhalation time (3 seconds for subjects aged 10 years and younger) 5. Maximum effort given by subject
Best Effort	A measurement calculated from a set of acceptable spirometry tests/manoeuvres
Multiple Breath testing	The subject breathes for 2-3 tidal breaths (rest breathing), takes a maximal inspiration through the flowhead, and then blows out rapidly until the subject has completely emptied their lungs
FEV25-75 FEF25-75	The mean forced expiratory flow during the middle portion of the FVC manoeuvre; the flow occurring between 25-75% of the exhaled volume
FEV1	The amount of air exhaled in the first second. Measured in L
FEV1 / FVC	Forced expiratory volume in 1 second divided by the forced vital capacity. This yields a ratio
Flow	The speed at which air is exhaled. Measured in L/s
Flow Volume Loop	A flow-volume curve that displays inspiratory and expiratory flow and volume
Volume Time graph	A volume-time curve
FVC	The maximum amount of air forcefully exhaled
Single Breath testing	The subject takes a maximal inspiration without the mouthpiece, inserts the mouthpiece into the mouth, and then blows out rapidly until the subject has completely emptied their lungs
PEF	The maximal expiratory flow generated during a FVC manoeuvre. Measured in L/min
1 second plateau	No change in volume for 1 or more seconds at the end of the expiratory manoeuvre
Pre-dose session	Spirometry session before bronchodilator or study drug administered
Post-dose session	Spirometry session after bronchodilator or study drug administered
Repeatability criteria	The two highest accepted FEV1 values should be within 0.15L (150mL) of each other. The two highest accepted FVC values should be within 0.15L (150ml) of each other. For subjects who have an FVC of <1 litre, the highest accepted FEV1 and FVC values should be within 0.10L (100mL)
Spirometer	An instrument used to measure air flow and volume producing graphical output indicating how well the subject's lungs are performing
Spirometry manoeuvre	A single spirometry manoeuvre
Spirometry session	Contains 3-8 spirometry manoeuvres

Step 1: Pre-test

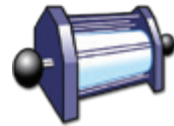
In accordance with guidelines, at the beginning of every spirometry testing day you should perform an accuracy check to ensure that the flowhead is functioning correctly; this is important as the spirometer is a measurement tool. Vitalograph can supply 1L or 3L precision syringes.

To perform an accuracy check:

- Connect it to the flowhead – there is no need for a filter



Connect the Vitalograph Compact flowhead to the 3L calibration syringe



Accuracy Check Icon

- Select the accuracy check icon in Spirotrac®
- Take your time and ensure you follow all the instructions and on-screen prompts

NOTE: You will be prompted to pump air through the flowhead several times to bring it to ambient temperature before starting the accuracy check procedure.

- When asked to withdraw the syringe ensure that the plunger is pulled out as far as possible before injecting the air
- You must wait at the end of each pump for new instructions



At the end of the accuracy check the software will automatically display the results. If the accuracy check is 'pass', you must press the 'Exit' button to close the screen.

If the results are **NOT** within the acceptable range: 2.9 - 3.11L, you must re-check the system accuracy.

Before you re-check the system, you must perform a series of equipment checks to ensure:

- The twin tubing is connected correctly (i.e. ribbed to ribbed and smooth to smooth)
- The twin tubing is not pinched
- The flowhead is at ambient temperature



- The flowhead is dry
- You have withdrawn the plunger as far as it would go and re-inserted all the way

After performing the above checks, you can repeat the accuracy check procedure by selecting 'Re-Check'. If the results of the re-check are still not within $\pm 3\%$, the software may recommend that the calibration is updated. If you are confident that there is not a problem with the equipment or your technique you may perform a calibration update.

At the subject's initial visit it is important to discuss and agree on their attributes and enter their details correctly into the software. Details include gender, age, height; these parameters affect their spirometry predicted values.

How the subject should prepare for the test:

- No smoking for one hour before test
- No alcoholic drinks within four hours of test
- No large meals within two hours of test - a 'large' meal is considered to be an amount which leads to the subject feeling uncomfortable
- No tight fitted or restrictive clothing
- No vigorous exercise within 30 minutes of test

Step 2: Test

Spirometry is effort dependent. The subject must understand that they need to give maximum effort.

15% greater volume can be achieved with good coaching.

- The patient should assume the correct posture: seated, feet flat on floor with head slightly elevated, looking ahead and chin pointed forward. It is recommended that the subject should be seated in a chair with arms.
- Ensure the patient is comfortable and unrestricted. They should have removed any ties or scarves and loosened any tight clothing around the neck.
 - For patients who wear dentures, if they fit well they should be worn during spirometry. Loose dentures should be removed
- Explain and demonstrate the spirometry test
- Ask the patient to attach a nose clip
- Place the disposable mouthpiece / BVF in mouth with tongue underneath the mouthpiece and the lips forming a tight seal around the mouthpiece
- Instruct the patient to take a deep breath in, filling their lungs with air
- Instruct the patient to blow out as hard and as fast as they can without any hesitation
- Instruct the patient to keep blowing until they have completely emptied their lungs
 - The patient may feel like they cannot breathe out any longer, the flowhead will detect low air flow, ensure they keep their back straight throughout the manoeuvre
- Instruct the patient to breathe in to signify the end of the manoeuvre
- Instruct the patient to take the mouthpiece out of their mouth and relax



Good Posture

Bad Posture

NOTE: Patients 10 years of age and younger should be encouraged to blow out air for a minimum of 3 seconds

Review the spirometry manoeuvre and inform the patient if they are doing well or advise them on how to improve their technique.

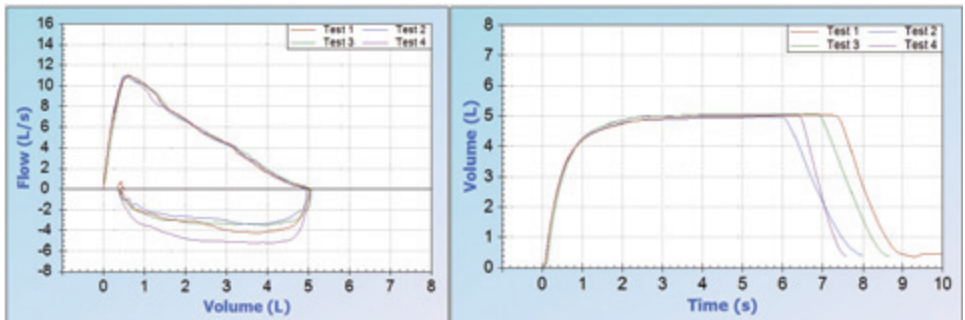
It is important to allow adequate rest times between the manoeuvres as this could affect the maximum effort of the patient.

Step 3: Post test

Review the manoeuvre to assess whether the acceptability criteria have been met. Consider:

- Was the start of test satisfactory?
- Was the minimum expiration time met?
- Is there a 1 second volume plateau at the end of the manoeuvre before inspiration?
- Was maximum effort given by the patient?
- Was there a cough in the first second?

Each manoeuvre should be checked individually against the acceptability criteria.



Graph 1: Example of a good spirometry session

Review the flow-volume and volume-time graphs to assist you. The accepted tests should be reviewed as a session, comparing the results to determine if they are repeatable.

- Have 3 acceptable tests been performed?
- The two highest accepted FEV1 values should be within 0.15L (150ml) of each other
- The two highest accepted FVC values should be within 0.15L (150ml) of each other

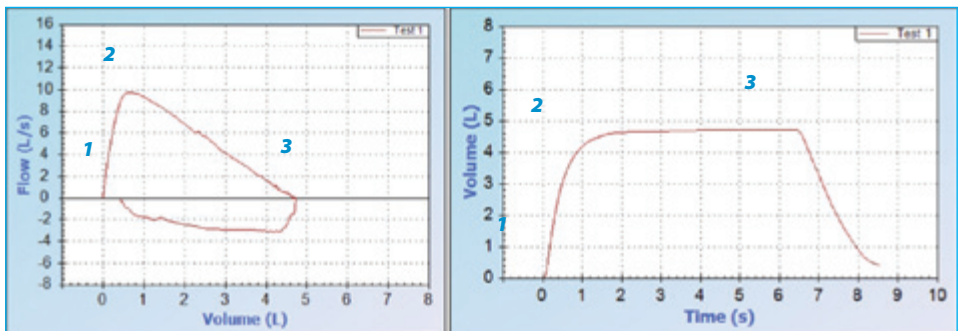
Failed test – If the acceptability and repeatability criteria are not met after 8 attempts, in accordance with guidelines, you should stop testing.

Error recognition

A good understanding of the acceptability criteria will enable you to recognise errors and advise you how to correct them; consider:

- Does the patient understand the instructions?
- Was the start of test satisfactory?
- Was there no glottis closure, mouth obstruction or leakage?
- Does the manoeuvre display a 1 second volume plateau?
- Was the minimum exhalation time met?
- Was the exhalation smooth and continuous?
- Did the patient give maximum effort?

Graph 2 is an example of a good spirometry test. At the start of the manoeuvre there is a sharp rise within the first second of the manoeuvre without any hesitation. The manoeuvre is smooth and lasts longer than 6 seconds. There is a 1 second volume plateau on the volume-time graph.



Graph 2: Example of a good spirometry test

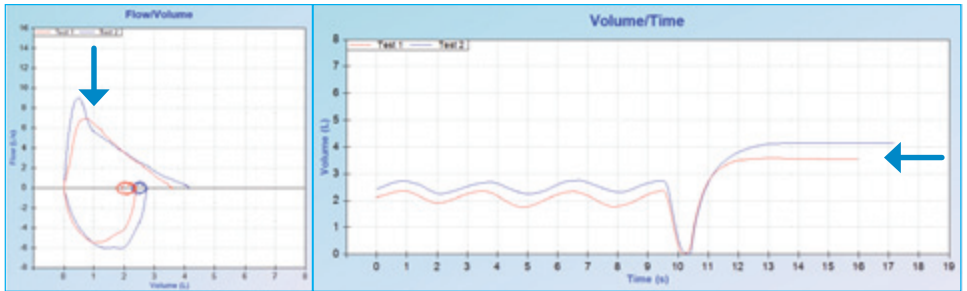
1. No hesitation.
2. Fast increase to peak expiratory flow.
3. Manoeuvre longer than 6 seconds, no abrupt end.

Examples of errors and how to resolve them

Error 1: Submaximal inhalation

Patient did not fully inhale before performing the manoeuvre.

Solution: Tell your patients to completely fill their lungs each time.

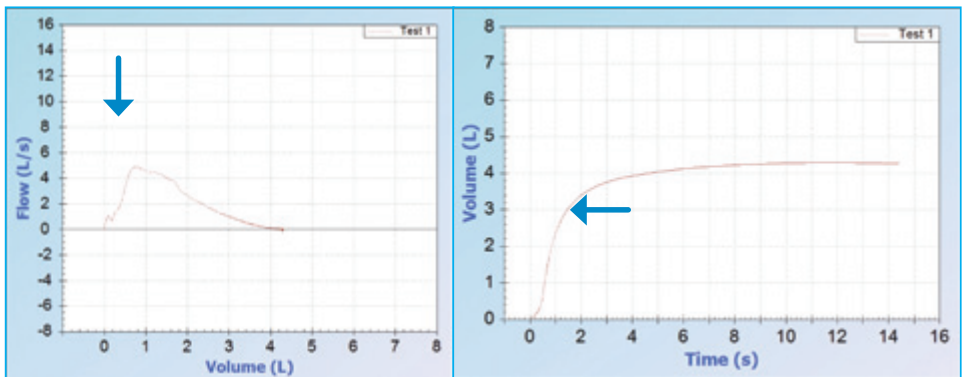


Graph 3: Multi breath test to show submaximal inhalation

Error 2: Slow start

Patient hesitated before exhaling.

Solution: Patients should 'blast' the air out of their lungs immediately and without hesitating.

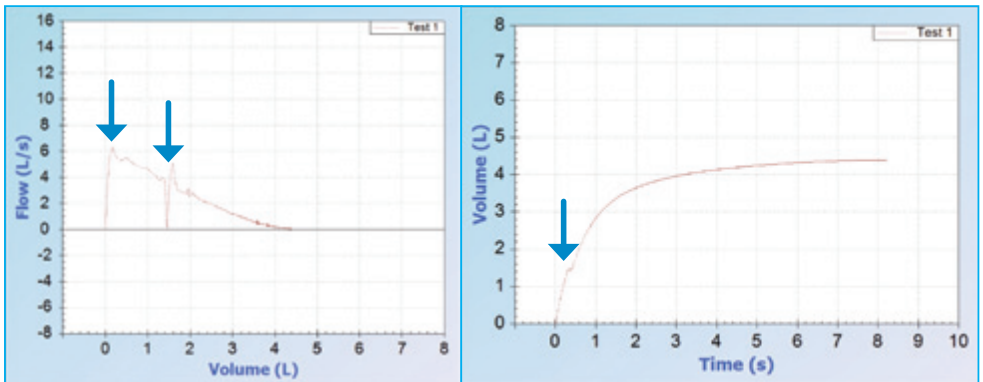


Graph 4: Single breath test to show 'Slow start'

Error 3: Cough

Patient coughed within first second of the manoeuvre affecting the FEV1 measurement.

Solution: Coughing is difficult to avoid – offer the patient some water and give them a rest between tests.

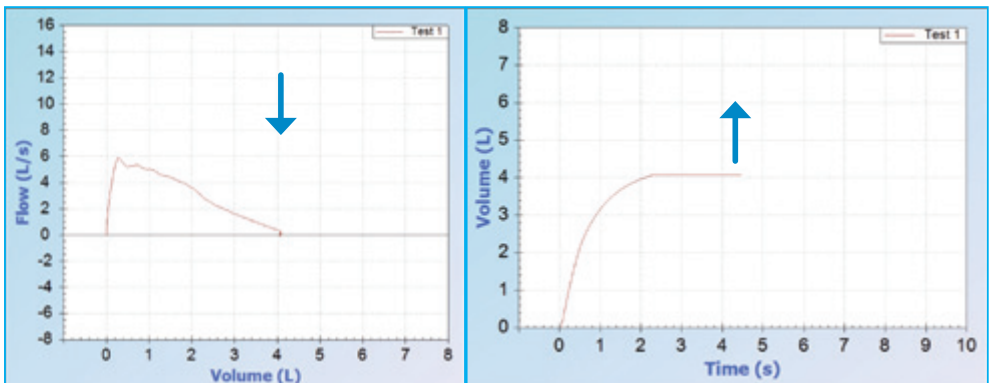


Graph 5: Single breath test to show a cough in the first second

Error 4: 'Early glottis closure', abrupt end

Can be caused by patient lowering their head whilst performing the manoeuvre.

Solution: The patient should keep blowing for 6 seconds and until they have completely emptied their lungs.



Graph 6: Single breath test to show early glottis closure and abrupt end

Thank you for reading this guide.

We hope this guide has been useful in expanding your understanding of performing spirometry using Vitalograph equipment.

Vitalograph is a world leading provider of outstanding quality cardio-respiratory diagnostic devices, clinical trial services and medical equipment servicing. With a pioneering heritage of excellence spanning half a century Vitalograph continues to make valuable contributions to effective medical care and enhanced quality of life.



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