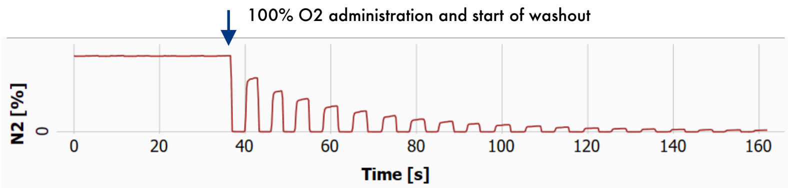
Multiple Breath Washout (MBW) and Key Parameters

Multiple Breath Washout

The multiple breath washout (MBW) is a powerful technique to detect ventilation inhomogeneities and early lung disease.[1,2] It is more sensitive than FEV1 measured by spirometry.[3]

The MBW measures how fast an inert tracer gas is cleared from the lungs during normal tidal breathing. Usually, nitrogen (N_2) is used as inert tracer gas and washed out by 100% oxygen (O_2). As it has been observed that infants change their breathing pattern upon pure O_2 inspiration, sulfur hexafluoride (SF_6) is the preferred tracer gas in infants.[2] SF_6 is administered in a pre-washout phase and then washed out by ambient air.

The end-point of the washout is historically defined as 1/40th (2.5%) of the starting tracer gas concentration (alternatively 1/20th or 5%).[4,5]



The washout curve shows how the exhaled tracer gas concentration decreases with every breath.

Advantages of MBW

- Non-invasive method
- Suitable for all ages, from infants to adults
- No patient cooperation required: test requires only tidal breathing
- Good indicator of lung function and ventilation inhomogeneity
- Detection of early pathogenic lung changes
- More sensitive than Spirometry/FEV1

EXHALYZER®D

The EXHALZYER®D offers comprehensive pulmonary function testing including single and multiple breath washouts (N_2/SF_6):

- Fully compliant to ATS/ERS guidelines[1,2]
- High accuracy with state-of-the-art components
- Step-by-step user guidance with SPIROWARE® software
- Automatic quality control of key parameters facilitating the evaluation process
- Straight-forward report generation with one click

FRC – Functional Residual Capacity

The functional residual capacity (FRC) is defined as lung volume remaining in the lung after tidal expiration. It is calculated by the cumulative expired volume (CEV) of the inert gas divided by the difference between the end-tidal concentrations of inert gas (Cet) at the start (Cet_{start}) and end (Cet_{end}) of the washout.[1,5]

$$\text{FRC} = \frac{Volume\ of\ exhaled\ tracer\ gas\ (CEVtracer_{\ gas})}{Cet_{\ start} - Cet_{\ end}}$$

LCI – Lung Clearance Index

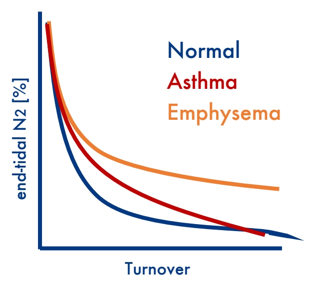
- LCI is an indicator of lung function, in particular of the function of small airways, where the gas exchange takes place.
- LCI reflects how well the lung is ventilated i.e. whether ventilation inhomogeneities are present.
- LCI is a unitless ratio between the total expired air volume required to reduce the tracer gas to 1/40th of starting concentration (CEV) and the functional residual capacity (FRC). The division by FRC normalizes the LCI and corrects for lung size.

$$\text{LCI} = \frac{cumulative\ expired\ volume\ (CEV)}{FRC}$$

For example, an LCI of 7 means the patient needs to turnover his FRC 7 times to clean the lung (normal range 6.5 to 7.5).

Moment Ratios

Moment ratios objectively estimate ventilation inhomogeneity, independent of the individual's lung volume, tidal volume, and breathing frequency.[6]



Moment ratios describe the skewness (shape) of the washout curve and indicate whether the initial or end of the washout was elongated. They also allow comparison of different curves.

M0 depicts the area under the curve, M1 the center of gravity of that area and M2 accentuates the tail of the curve.

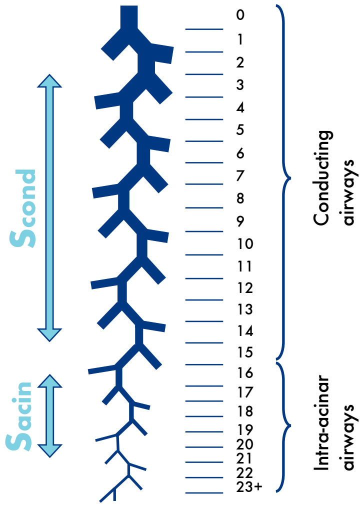
The washout curve is most often quantified by the normalized first moment **M1/M0** and the normalized second moment **M2/M0**.

Slope Analysis: Scond and Sacin

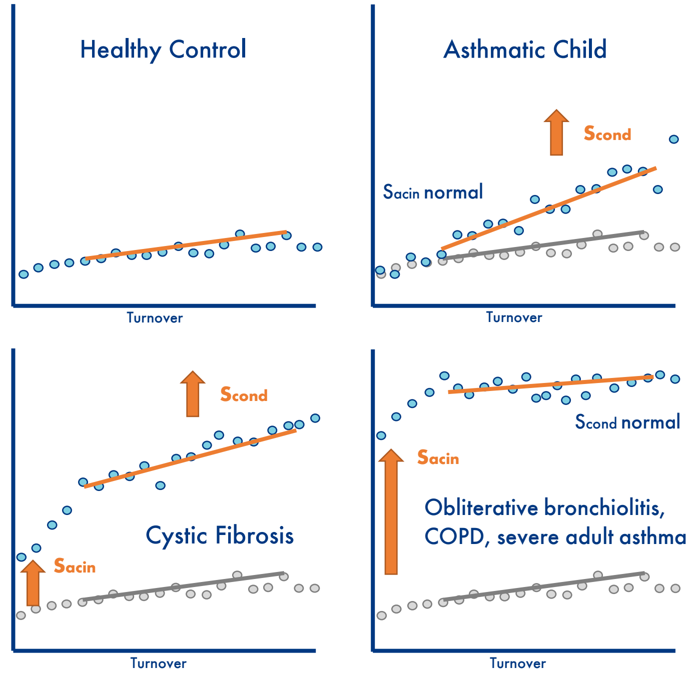
The MBW derived indices Scond and Sacin provide information on the location of the pathological process.[1,5,7] For each breath of the washout, the slope of the N_2 concentration during phase III (alveolar phase) is determind and normalized by the mean expired N_2 of that breath. The normalized slope is larger, the larger the ventilation inhomogeneity.

Scond (N_2 slope conductive airways) is the slope of the re-gression line of Sn versus lung turnover between 1.5 and 6 turnovers. It reflects diffusion-convection interaction-dependent inhomogeneity (DCDI).

Sacin (N_2 slope acinar airways) is the Sn value of the first breath minus the contribution from Scond to the first breath. It reflects convection-dependent inhomogeneity (CDI).



Typical Slope Fingerprints



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2. Robinson, P. D. *et al.* Preschool Multiple-Breath Washout Testing. An Official ATS Technical Statement. *Am J Respir Crit Care Med* **197**, e1–e19 (2018).
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