LUNG FUNCTION ASSESSMENT BY IMPULSE OSCILLOMETRY IN ADULTS

Terrence Shenfield MS, RRT-ACCS, RPFT, NPS, AE-C

OBJECTIVES

Describe what is Impulse Oscillometry

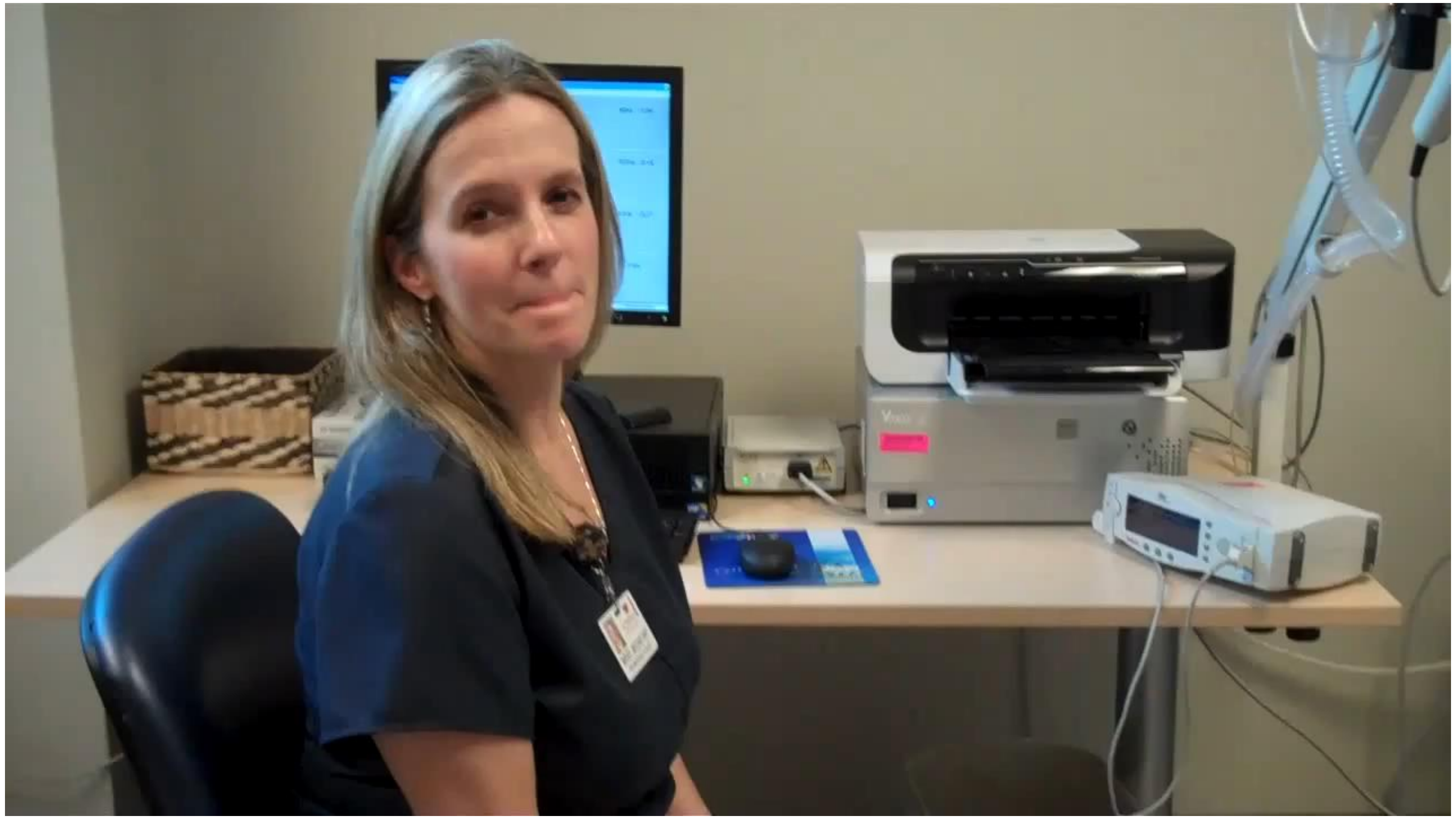
Describe the advantages over spirometry

Describe the structure of the Impulse Oscillometry system

Describe different pulmonary disorders that benefit from Impulse Oscillometry

WHAT IS IMPULSE OSCILLOMETRY?

SHORT VIDEO ON IMPULSE OSCILLOMETRY



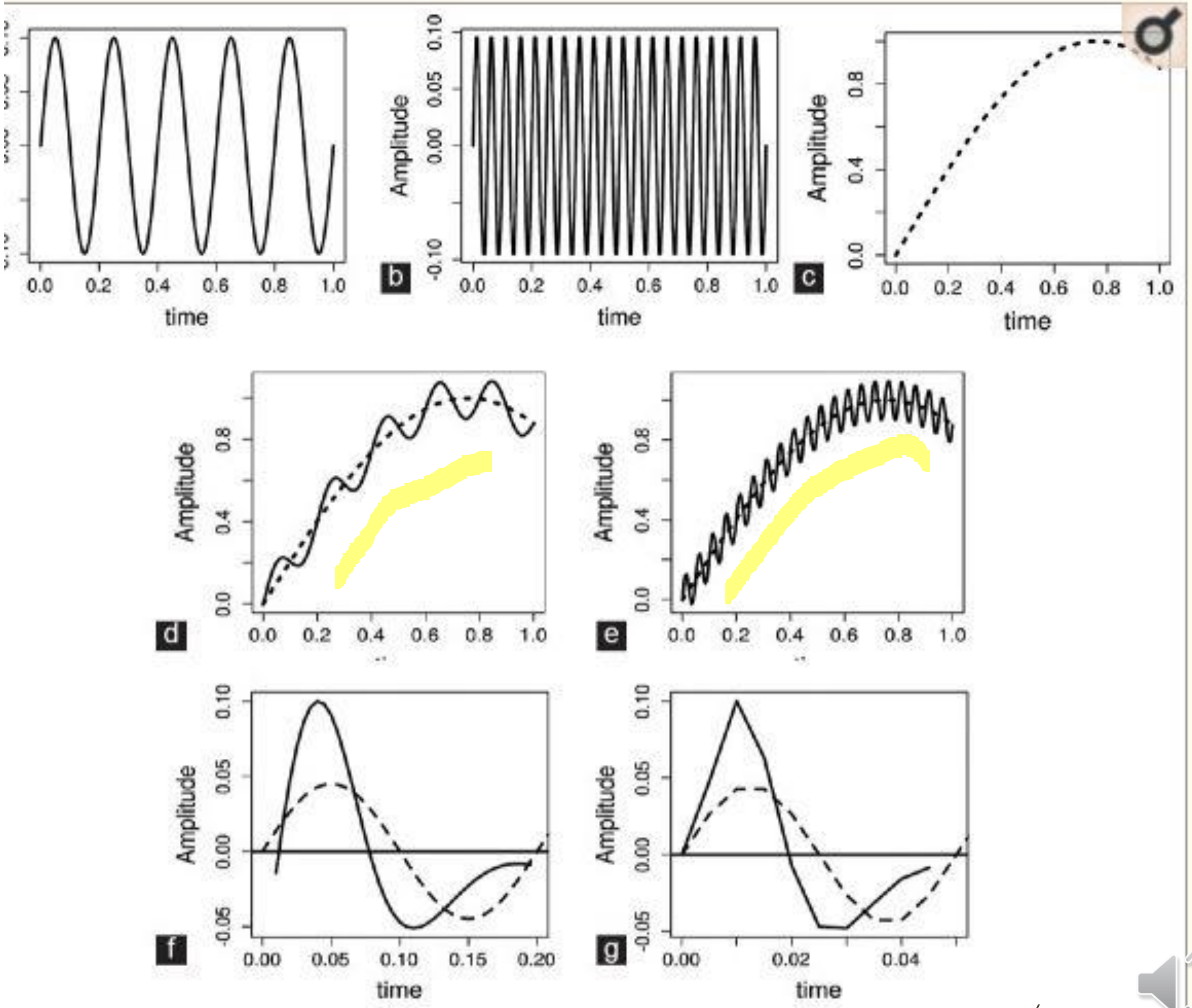
INTRODUCTION

Impulse oscillometry (IOS) is a variant of forced oscillation technique, described by Dubois over 50 years ago.

Sound waves are superimposed on normal tidal breathing, and the disturbances in flow and pressure caused by the external waves are used to calculate parameters describing the resistance to airflow and allow measurement of lung mechanics.

Requires minimal patient cooperation

IMAGE OF RESULTS



MAIN ADVANTAGES

Performing the test is relatively easy since it is a passive method that requires minimal cooperation

It measures resistance and reactance at different frequencies in lung offering important information about regional inhomogeneity and lung periphery.

Only requirement is for the subject to be relaxed and breathing normally while sound waves are being superimposed on the breathing.

Can detect subtle changes in the small airway function even in the setting of normal spirometry, as illustrated above, thus providing valuable information for early diagnosis and monitoring of airway diseases.

STRUCTURE OF THE OSCILLOMETRY SYSTEM

Sound waves, generated with the help of a loudspeaker are transmitted into the lungs of the subject.

These sound waves, which are essentially pressure waves, cause changes in the pressure and this change in pressure drives changes in airflow.

By measuring the magnitude of change in the pressure and flow, one can determine the mechanical properties of the lung.

Waves of lower frequencies travel deep into lungs till alveoli and are reflected back while those of higher frequencies are reflected from the larger airways.

TECHNIQUE DESCRIPTION

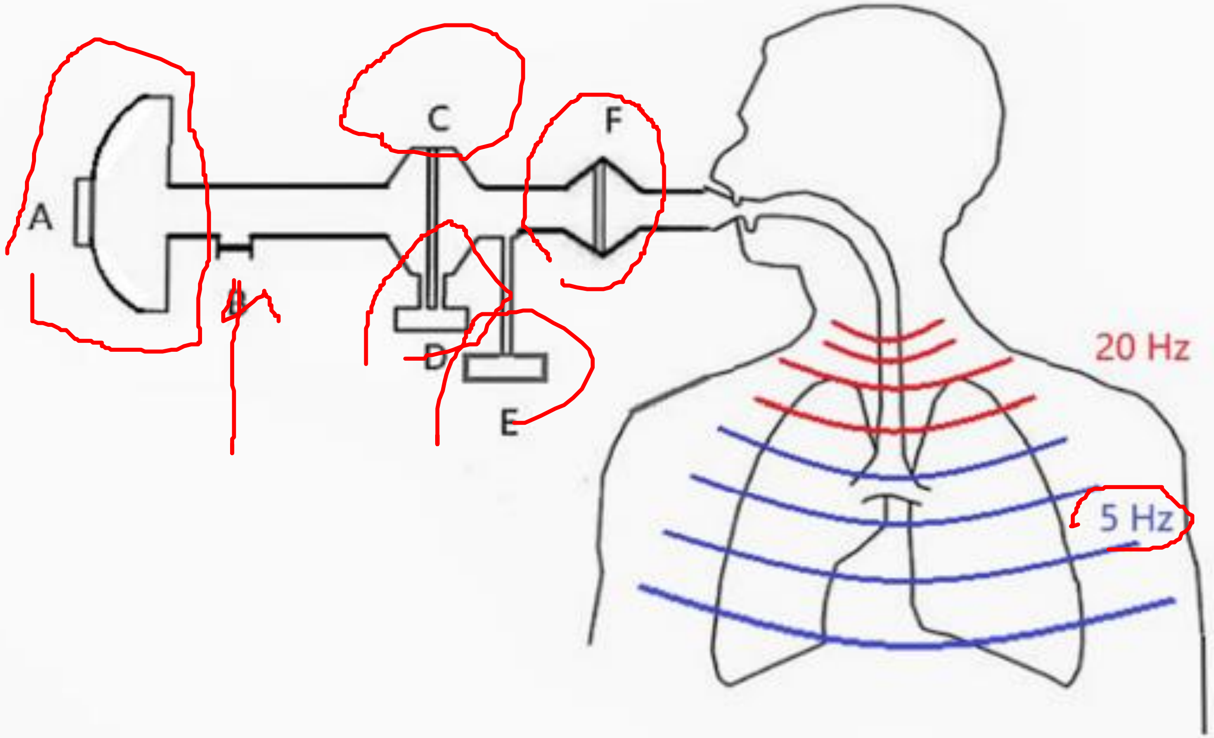
An impulse consisting of a mixture of sound waves of different frequencies is generated by the loudspeaker at the mouth.

As this wave passes into the lungs, it causes changes in pressure as well as in the flow of air.

The frequencies of the waves delivered in IOS ranges from 5 to 30 Hz.

While frequencies higher than 30 Hz can cause discomfort to the patient.

A pressure transducer and a pnuemochromatograph are present at the mouthpiece, to measure the pressure and flow.



A. Loudspeaker
B. Bias flow
C. Pneumotachograph
D. Airflow
E. Airway opening pressure
F. Mouthpiece and bacterial filter

IMPULSE OSCILLOMETRY PARAMETERS AND THEIR INTERPRETATION

- Impedance
- Resistance
- Reactance
- Resonant frequency
- Area of resistance
- Coherence
- Reference values

IMPEDANCE

Respiratory impedance is the sum of all forces which oppose the generated impulse.

Impedance measured at any frequency is the ratio of the difference in pressure and changes in the flow at that frequency.

Depending on the region where the pressure is measured, the impedance varies.

RESISTANCE

The resistance derived from impedance includes the resistance due to central airways, peripheral airways, lung tissue, and chest wall, although the latter two are usually negligible.

Almost, 80% of the resistance is contributed by central airways and only 20% by small airways (<2 mm in diameter) in adults.

REACTANCE

Reactance includes two components, the inertia of the air column to move (inertance) and the capacitance of the lung.

Capacitance can be interpreted as a property which reflects elasticity of the lung.

The capacitance component of the reactance is defined to be negative in sign and inertance is defined as positive.

RESONANT FREQUENCY

Resonant frequency (fres) is defined as the frequency at which the inertial properties of airway and the capacitance of lung periphery are equal

The frequency at which total reactance is zero.

We cannot attribute fres to a specific mechanical property of lungs, but it can be used to separate low frequencies where capacitance component dominates from high frequencies where the inertial component takes over.

The normal value of fres in adults is 7-12 Hz.

COHERENCE

Coherence is another important parameter and is used to determine the validity and quality of the test results.

It reflects the reproducibility the impedance measurements.

It is a value between 0 and 1 and, ideally, should be >0.8 at 5 Hz and >0.9 at 20 Hz for the measurement to be considered valid.

SO! WHY DO YOU WANT TO OFFER THIS TEST RATHER THAN SPIROMETRY?

Portable device

Easy maintenance

Easy calibration

User friendly for both patient and clinician

Able to export data

Impulse Oscillometry Terminology

Impedance (Zrs)	A calculation of the total force needed to propagate a pressure wave through the pulmonary system, comprised of resistance and reactance.
Resistance (Rrs)	Energy required to propagate a pressure wave through the airways; to pass through the bronchi, bronchioles, and to distend the lung parenchyma. Resistance is determined when a pressure wave is unopposed by airway recoil and is in phase with airflow.
Reactance (Xrs)	Energy generated by the recoil of the lungs after distention by a pressure wave out of phase with airflow.
Area of Reactance (AX or XA)	Area under the curve between the reactance values for 5Hz and the resonance frequency.
Resonance Frequency (Fres)	The frequency at which the lung tissue moves from passive distention to active stretch in response to the force of the pressure wave signal; graphically when reactance is zero.
Coefficient of Variability (CV)	Statistical determinant of the trial-to-trial variability serving as an index of reproducibility.
Frequency Independent Change	When resistance values do not vary at different frequencies. If overall resistance is increased this may be indicative of proximal obstruction.
Frequency Dependent Change	When resistance varies with frequency more than age dependent normal values. This may be indicative of distal obstruction as shown by R5-R20.

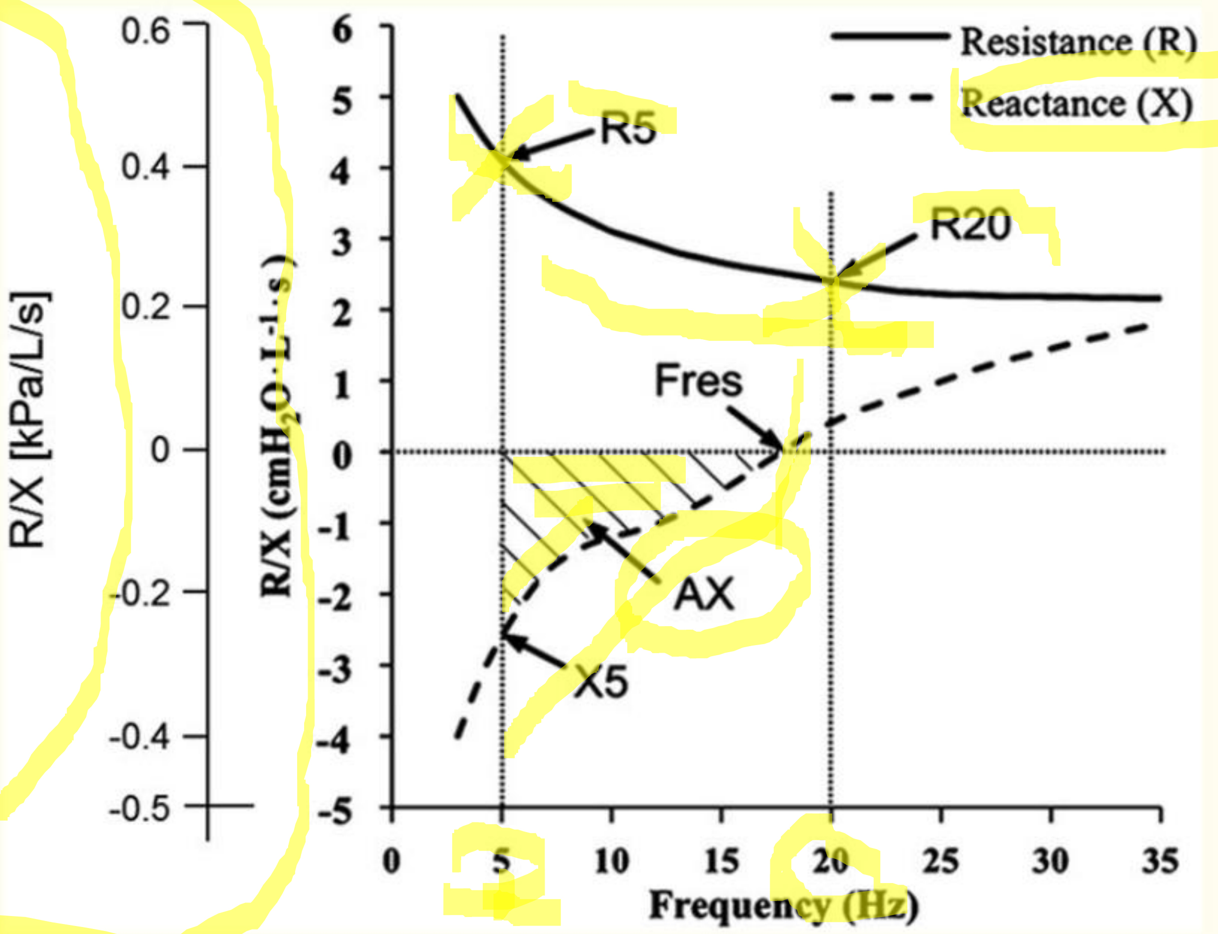


Figure 1

Schematic illustration of IOS indices over oscillation frequency (Hz), including R5, R20, Fres, X5, and AX. Shown is a typical IOS tracing produced during a 30 second trial. (With Permission–Shi Y. J Allergy Clin

Population Based IOS Reference Values in Healthy Adults

Ref	Study Site	Age	# of subjects	IOS Values Mean (SD) except * value calculated from a regression equation using 45 (age), 175 cm (height), and 70 kg (weight)	
				R_5 [kPa/L/s]	X_5 [kPa/L/s]
(50)$	**Australia**	**45* (25-74)**	**132**	**0.20***	**-0.11***
(51)	Europe	45* (45-89)	397	0.22*	-0.07*
(30)		45* (18-84)	368	0.23*	-0.09*
(52)		40.5 (27-66)	12	0.29 (0.07)	-0.09 (0.03)
(53)		43 (24-73)	12	0.31 (0.13)	-0.11 (0.04)
(54)		37 (2)	18	0.38 (0.02)	-0.11 (0.01)
(55)		48.3 (3.9)	18	0.32 (0.03)	-0.10 (0.01)
(56)	North America	NA	29	0.28 (0.05)	NA
(57)	Asia	18-65	21	0.29 (0.08)	-0.08 (0.05)
(58)		47.6 (2.5)	29	0.26 (0.10)	-0.10 (0.01)

KEY TAKE AWAY POINTS

For adults, both R5 and X5 values were similar regardless of demographic or geographical differences.

R5and X5 values, the most reported IOS parameters in children, show wide variations at a given height and age.

CLINICAL APPLICATIONS

Response to Broncho-Dilatators

Broncho-Provocation Testing

Asthma and COPD

Interstitial Lung Disease (ILD)

Impairment of Lung Function Due to Exposure to Occupational Hazards or Smoking

Central Airways Obstruction

Cystic Fibrosis

Other Diseases – Graft Function, Lung Transplant, Sickle-Cell Disease

RESPONSE TO BRONCHO-DILATATORS

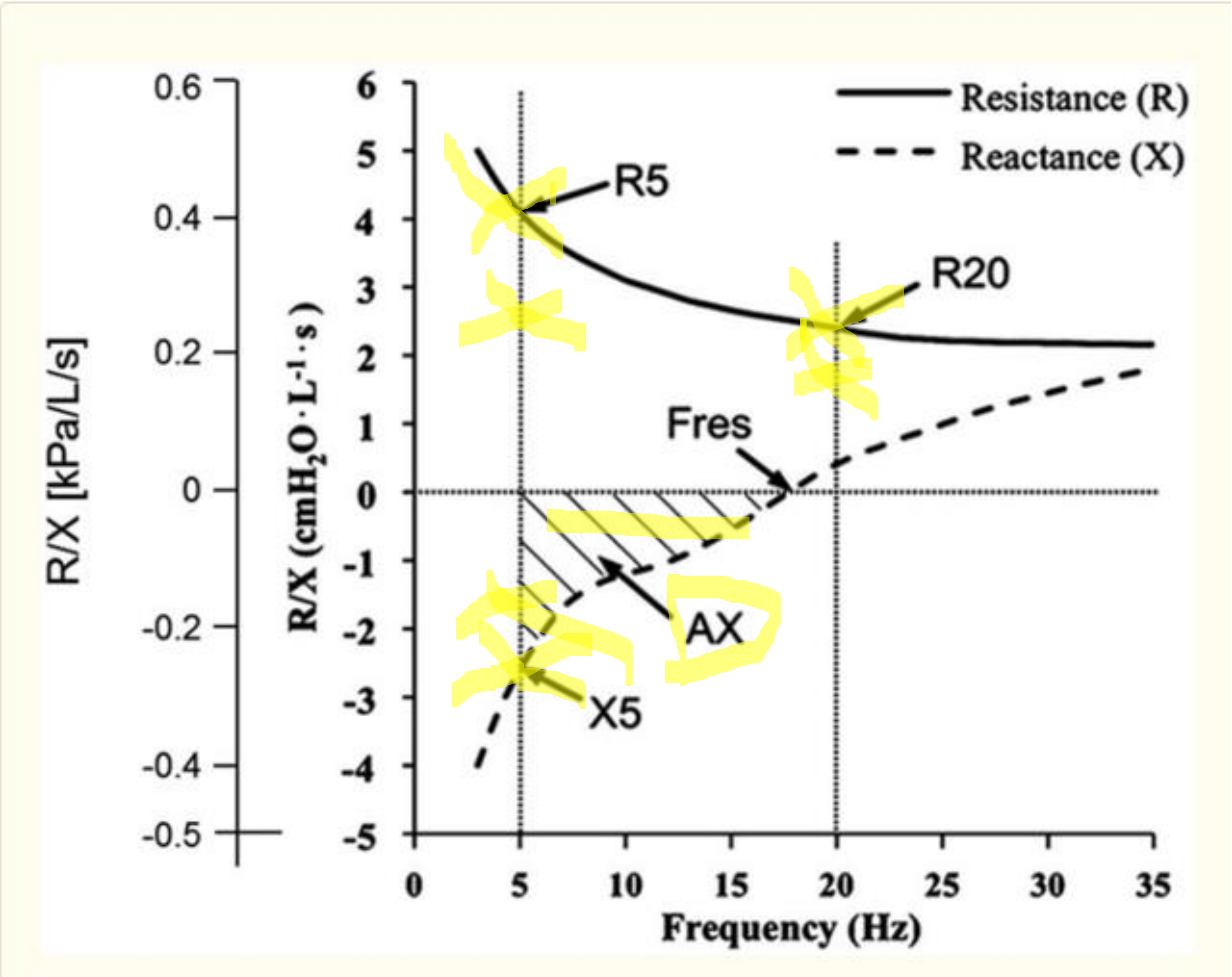
Studies showed that IOS has more sensitivity than spirometry in the case of children as a predictor of asthma and response to treatment

IOS can be as useful as spirometry in assessing treatment

Oscillometric parameters are highly sensitive to broncho-dilatation, especially in early stages of COPD. Response to treatment of COPD patients.

The BDR assessed by IOS is demonstrated by the reduction of resistance Rrs including R5, frequency dependent R5-R20, and reactance (Xrs) AX

Data suggest that a BDR response greater than a 40% decrease in R5 be considered a positive BDR, signifying significant airway reversibility in children and adults

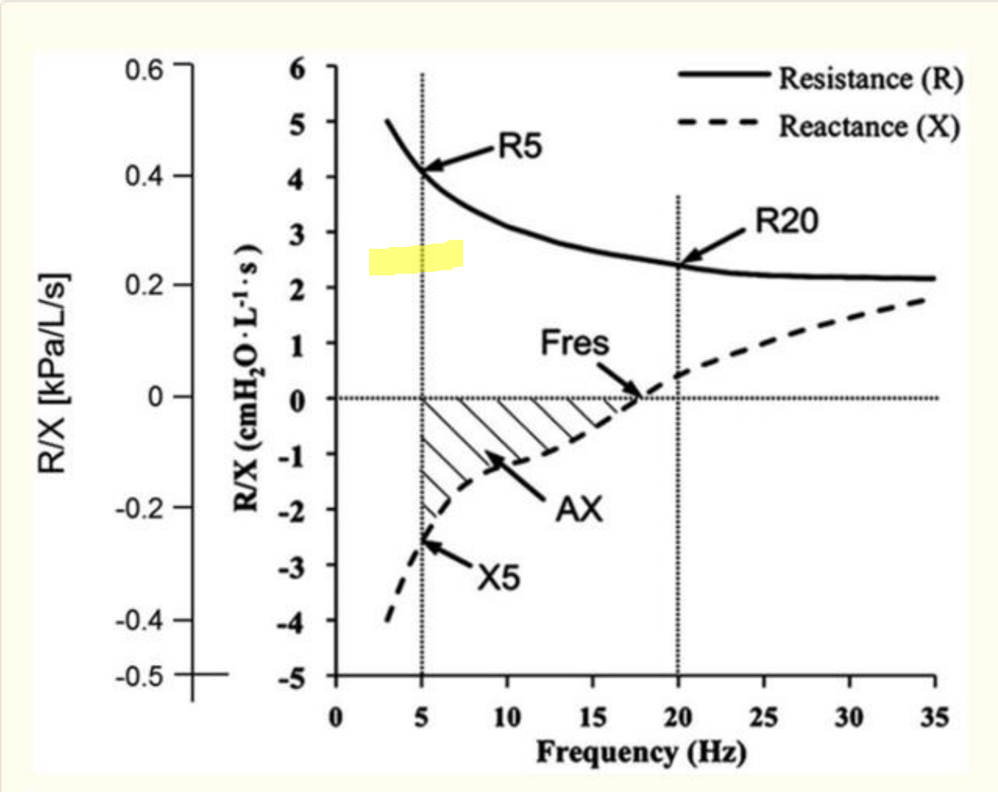


BRONCHO-PROVOCATION TESTING

Broncho-provocation testing can be performed in order to assess airway hyper-responsiveness using various agents like histamine, methacholine, and other allergens.

When using methacholine or histamine challenge the threshold is conventionally measured using spirometry to determine the provocative concentration (or dose) required to produce a 20% fall in FEV1

A study published by Naji et al. concluded that using oscillometry as an alternative method for measuring resistance and obstruction may be useful when patients cannot perform body-plethysmography or spirometry exercise testing.

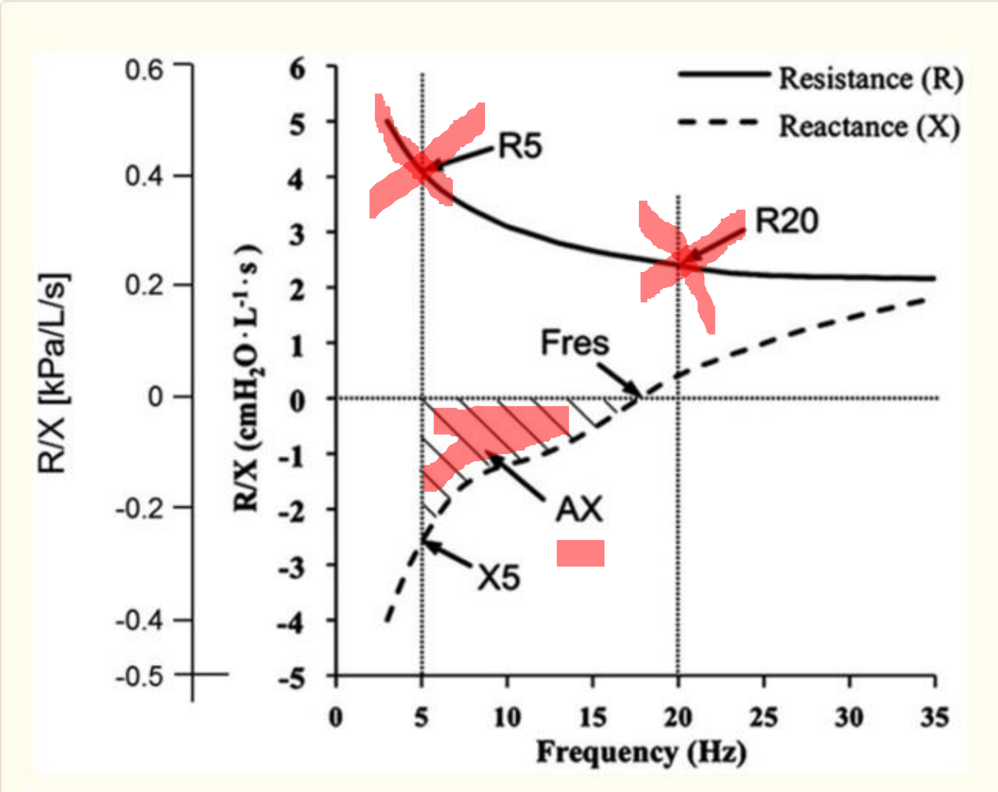


ASTHMA AND COPD

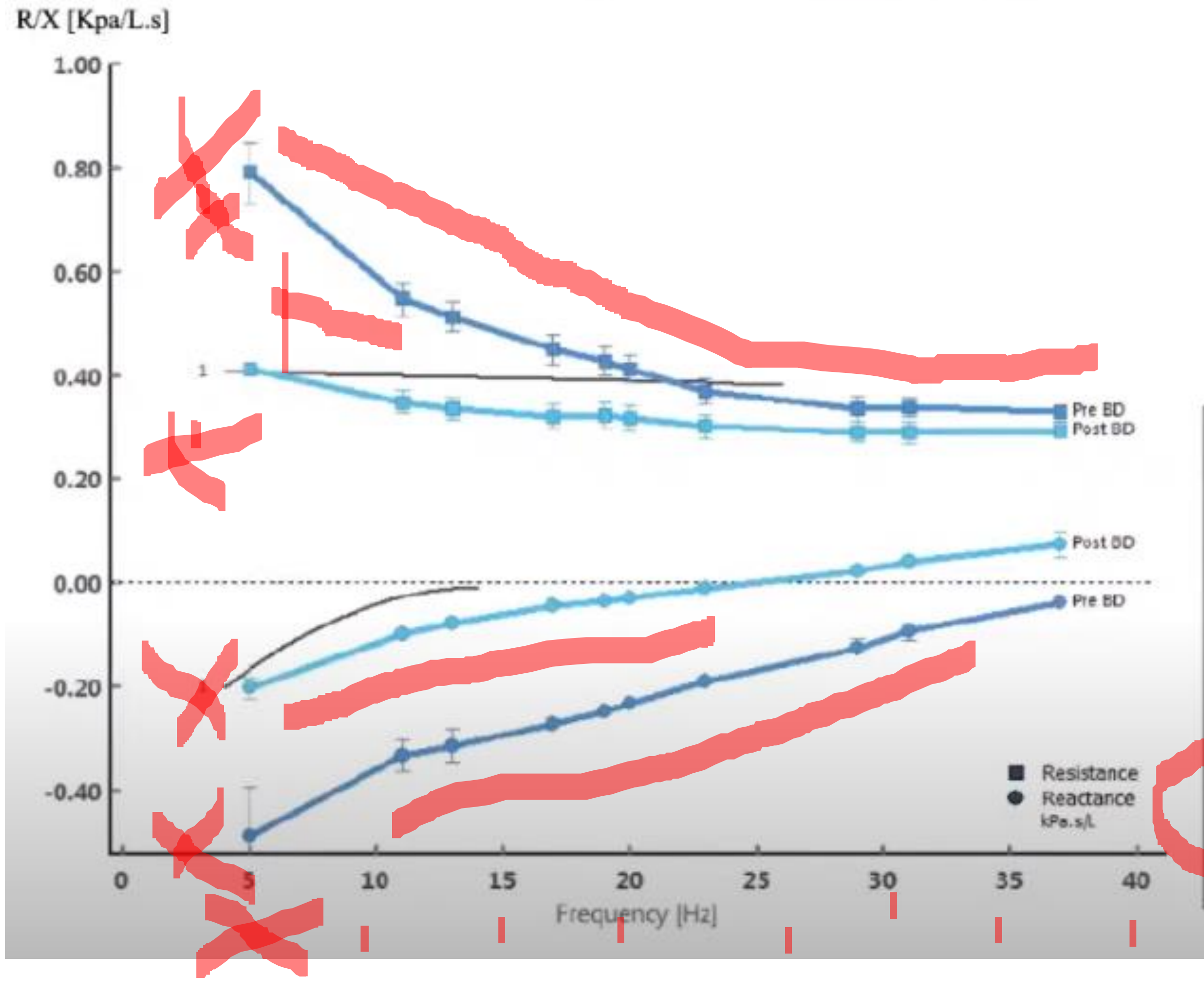
The most often researched lung diseases with oscillometry of all is asthma. Airway resistance increases (especially in small airways) in the case of patients with asthma, mainly during exacerbations

Oscillometry is also a useful tool in evaluating the control level of asthma.

Detecting treatment response in asthma is also a feature of oscillometry, especially by assessment of the changes in the reactance area (AX)



AO reversibility to salbutamol in severe asthma



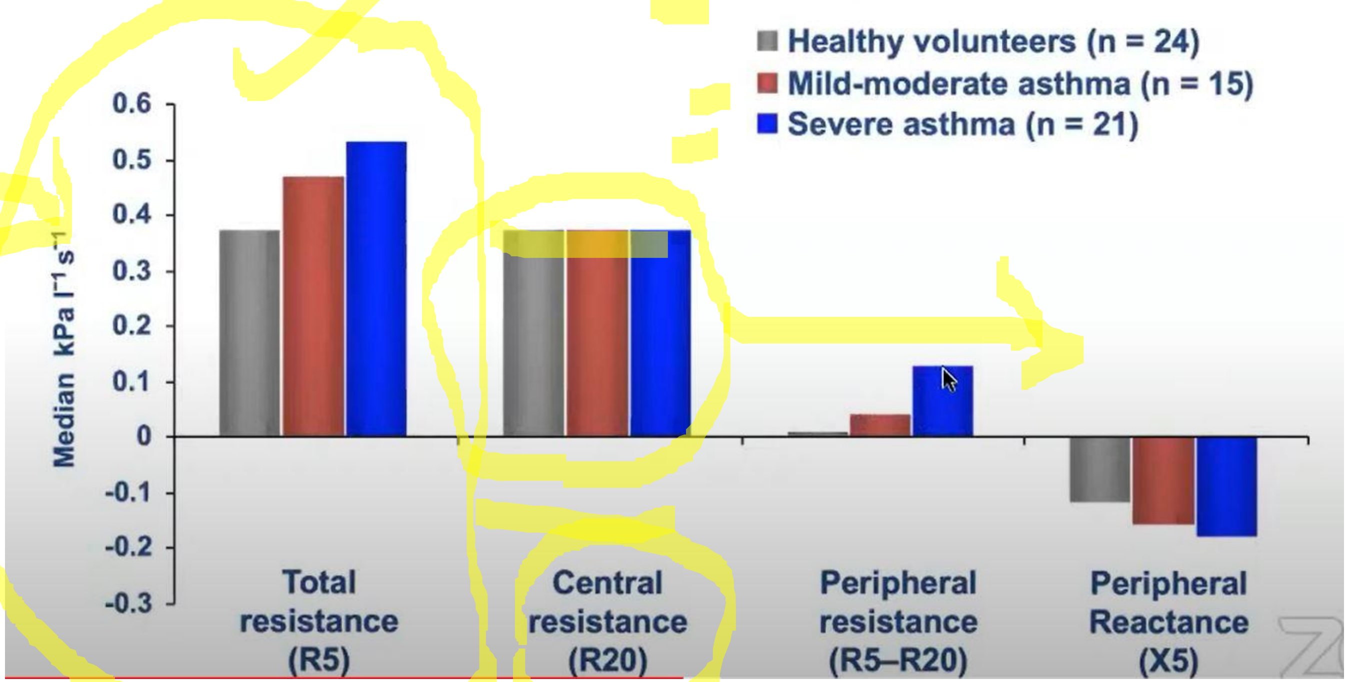
Prof Brian

Reversibility:

- R5 = 48%
- R20=23%
- R5-20 =75%
- AX=79%
- X5=58%
- FEV1=16%
- FEF25-75=15%

IOS(AO) AND ASTHMA SEVERITY

- Except for central resistance, all AO parameters showed increased abnormality with increased asthma severity and airflow obstruction



Reversibility in asthma and COPD

% Reversibility to salbutamol 400ug:

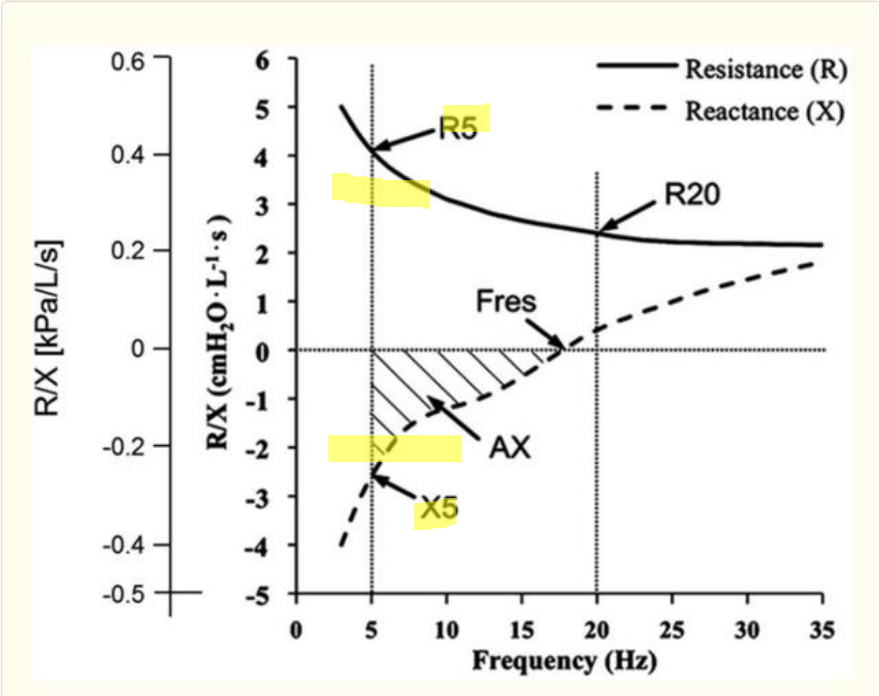
- FEV1 : Asthma 8% vs COPD 8%
- AOS AX : Asthma 40% vs COPD 24%

INTERSTITIAL LUNG DISEASE (ILD)

Modified values of reactance and resistance can appear in consequence of small airways inflammation, or in association with modified elastic recoil pressure and reduced lung volume in both obstructive and restrictive diseases

Recent study conducted by Reham et al. studied correlations between oscillometry and spirometry on patients diagnosed with rheumatoid arthritis associated ILD, and concluded that IOS can be used as an early screening technique to identify proximal and distal pulmonary tissue affection even before spirometry changes appear

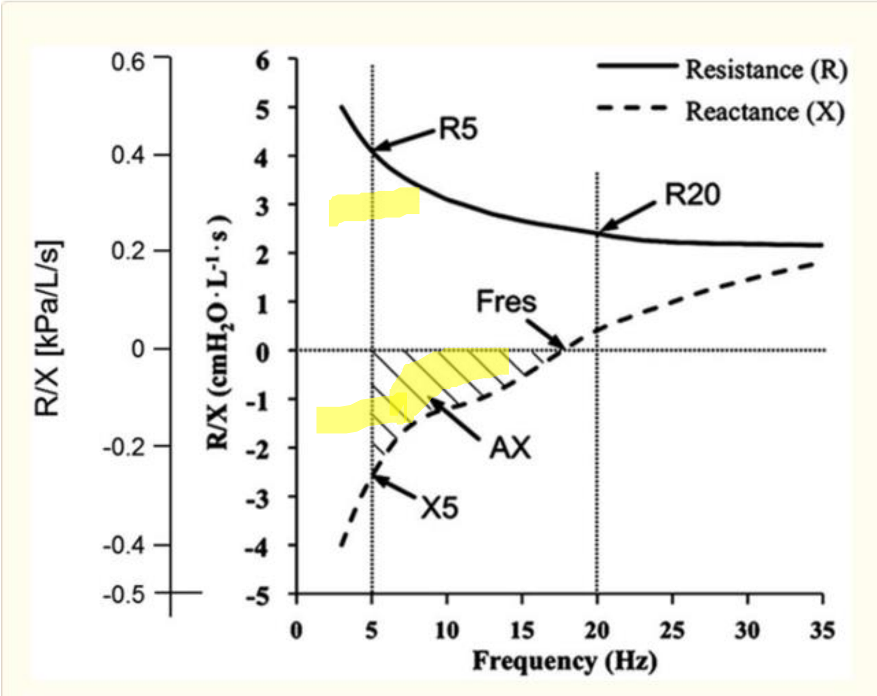
In another study by Mori et al. decreased X values (especially X5) were found in patients with ILD



IMPAIRMENT OF LUNG FUNCTION DUE TO EXPOSURE TO OCCUPATIONAL HAZARDS OR SMOKING

In an American study, Berger et al. showed that the forced oscillometry technique has high capacity in early diagnosis of airway disease.

In their study they performed oscillometry and spirometry on symptomatic subjects exposed to the World Trade Center dust, and while spirometry values were normal, they registered modifications on oscillometric parameters



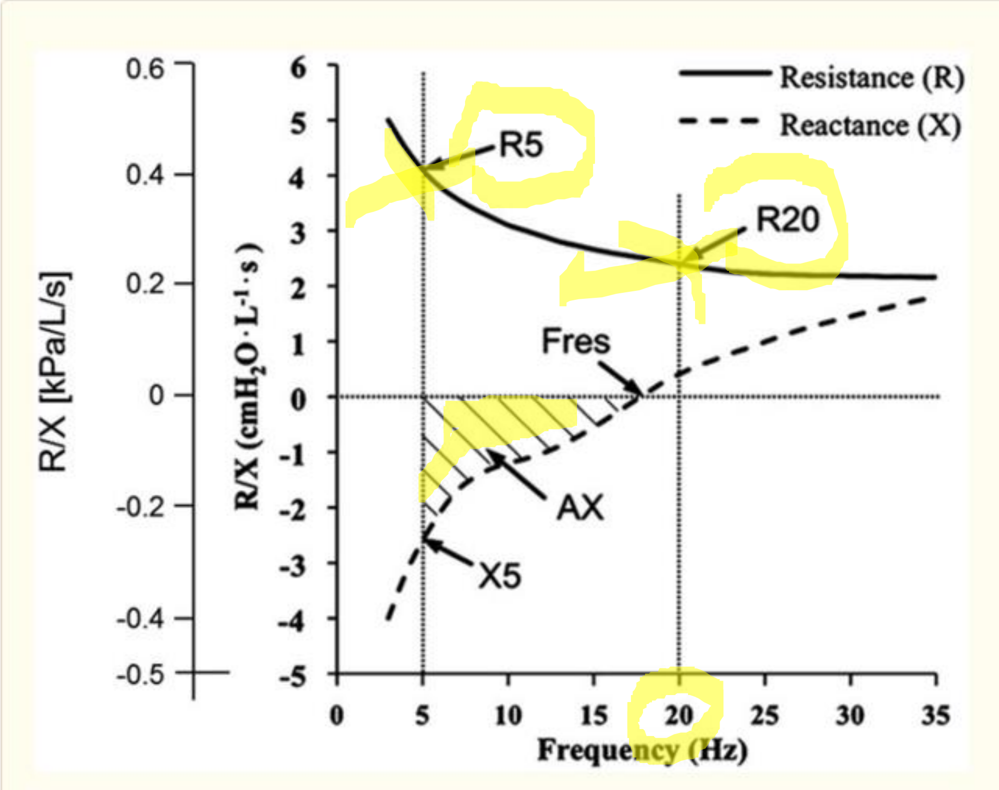
CENTRAL AIRWAYS OBSTRUCTION

A study published by Hnad et al. revealed evidence of the usefulness of oscillometry in the assessment of the central airway obstruction.

Central airway obstruction (CAO) refers to a variety of obstructive processes that impede airflow within the central airways, trachea, and mainstem bronchi. CAO may be secondary to malignant or benign disease, and represents a significant source of morbidity and mortality with a significant impact on quality of life

The advantage of oscillometry, being non-invasive and effort-independent, makes it a sustainable test for differentiating fixed and variable obstruction of central airways, also for monitoring before and after procedures, like bronchoscopy.

Another study concluded that the therapeutic results can also be estimated in the case of patients with central airway obstruction using the oscillometric parameter Rrs20.



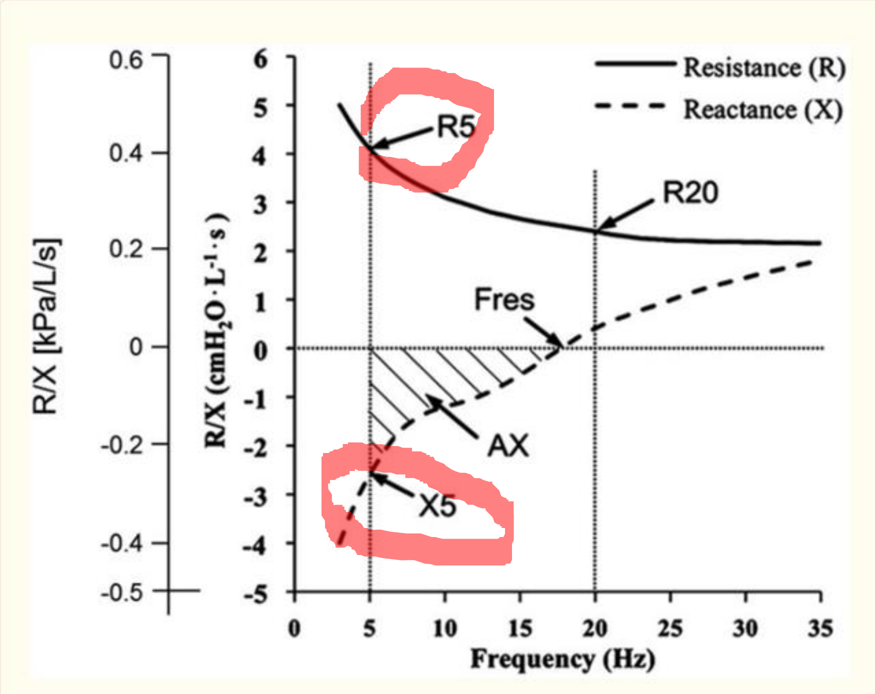
CYSTIC FIBROSIS

Most studies regarding cystic fibrosis have been published on children.

Research on oscillometric parameters in cystic fibrosis showed an increase in Rrs5, Fres, and a decrease of Xrs5 in phases of the exacerbation of the disease, and an improvement of these parameters after treatment.

A Brazilian study of 26 cystic fibrosis patients consisted in assessment of lung volume by computer tomography, DLCO, and IOS

Revealed that hypoventilated regions of the lungs correlate with increasing restrictive parameters of oscillometry and with reduced diffusing capacity of the lungs.



FUTURE DIRECTIONS

Implementing oscillometry to geriatric and pediatric clinics could be important in diagnosis and monitoring diseases, facilitating the adjustments of therapy.

Interstitial lung diseases with oscillometry need detailed research, since a radiation-free assessment in monitoring disease progression could be very beneficial.

Oscillometry can be a sensitive tool for diagnosing early stages of fibrosis (even before spirometric changes).

SUMMARY

This is a great tool to have with younger populations and older populations

Greater sensitivity with Asthma and COPD patients

Impaired patients due to cognitive and neurological diseases

ILD

Cystic fibrosis

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