Correlation of Forced Oscillation (FO) and Ventilatory Distribution Indices of Small Airway Function in Asthma

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Introduction

It has been demonstrated that ultrasonic flow sensors can determine not only the flow and volume of exhaled gas but also the molar mass (MM)[a]. The MM of exhaled gas has been utilized to characterize degree of airway obstruction[b] and quantify lung volume[c].

$$F = k_1 \frac{t_u - t_d}{t_u \cdot t_d}; \qquad MM = k_2 \cdot R \cdot T \left(\frac{t_u \cdot t_d}{t_u + t_d} \right)^2$$

The correlation of MM and volumetric capnography, measured by mass spectrometry, to identify airway obstruction has proven to be very strong. Thus, MM measurements may provide an effort-independent test to diagnose airway obstruction[b].

Forced oscillation (FO) measures breathing mechanics by superimposing small external pressure signals on the spontaneous breathing[d]. FO provides clinical information about smaller, more peripheral airways as well as large airways[e].

Methods

Asthmatic patients (n = 15) underwent FO (IOS, Jaeger), exhaled gas analysis using an ultrasonic flow sensor (prototype Spiroson X, ndd), and spirometry, in that order. IOS indices included frequency dependence of resistance (R5-R15) and integrated low frequency reactance (AX). Volumetric capnography indices included slopes of phase II and III (S2, S3). We compared asthmatic patients and COPD patients (n = 6) to include a broader range of small airway disease.

The following block diagram shows the setup of the MM system:

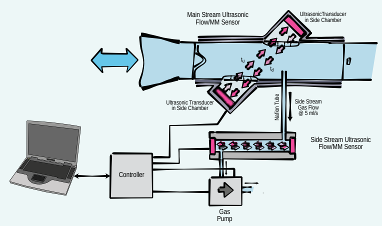
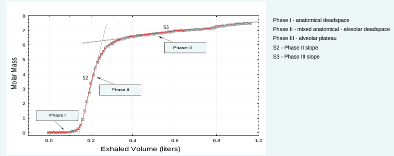


Figure 1

Observations

During quiet breathing the MM signal is representative of accepted capnograph waveform morphology, thus Phase I, II, III and respective slopes are clearly identified.



MM indices reflect conduit airways deadspace (S2) and uniformity of alveolar ventilation (S3): larger deadspaces yield smaller S2 and more uniform alveolar ventilation yields smaller S3. At low lung volumes, when both conduit and ventilatory airways constrict, both S2 and S3 will increase.

Figure 2 illustrates a normal male subject during (a) tidal breathing at normal end-expiratory lung volume (EELV), and (b) low-EELV breathing below FRC. During low-EELV breathing, S2 and S3 increase with associated increases in IOS total respiratory resistance (R5) and distal airway mechanical indices ([R5-R15] and AX). IOS and MM indices in asthmatic and COPD patients were explored with this model.

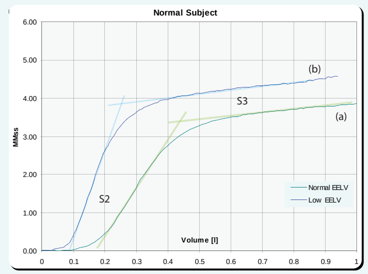


Figure 2

	Normal Tidal	Low - EELV	% Chg
S2	14.7	24.4	66.2
S3	0.89	1.09	23.2
R5	2.1	4	90.5
R15	1.8	3.2	77.8
AX	0.73	5.9	708

Results

Asthmatic and COPD patients with different degrees of small airway disease show associated differences in IOS and MM indices as predicted by lung volume-associated airway mechanics changes. Fig 3a illustrates a young steroid-naive male asthmatic and 3b, a middle-aged female COPD subject, both post-BA*. Deadspace is larger and ventilation nonuniformity is less in the male asthmatic, as reflected by both IOS and MM indices. The normal male subject in Fig 2 has similar MM indices at low EELV to the female COPD patient.

*bronchdilator agent

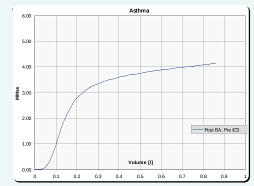


Figure 3a

	Data
S2	16.7
S3	0.67
R5	2.7
R15	2
AX	5.7

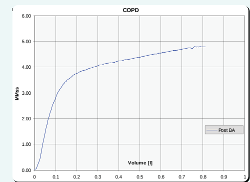


Figure 3b

	Data
S2	24.4
S3	1.7
R5	6.6
R15	4.3
AX	30.5

Conclusion

1) MM indices during resting tidal breathing reflect both conduit (deadspace) airways and peripheral airways that cause non-uniform distribution of ventilation.
2) Known changes in conduit and peripheral airways associated with decreased lung volumes cause predicted changes in MM indices
3) Differences in MM and IOS indices between asthmatic and COPD subjects are predicted by known lung volume-associated airway mechanical changes.
4) Further studies in both asthmatic and COPD subjects are warranted to assess correlations between MM and IOS indices during both tidal breathing and with extended volume excursions (near-TLC to near-RV).
5) Effects of anti-inflammatory interventions in patients with airflow obstruction are warranted to compare with beta agonist interventions.

References

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(e) Goldman M, Saadeh C, Ross D. Clinical Applications of Forced Oscillation to Assess Perhiperal Airway Function. Respiratory Physiology and Neurobiology 2005; 148:179-94