Allometric quantification of respiratory minute ventilation for chronic rhinosinusitis (CRS) subjects, using body mass

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Abstract

Objective: Topical drug delivery to areas of sinonasal cavity affected by chronic rhinosinusitis (CRS) is hypothesized to depend, amongst other factors, on breathing techniques during nasal spray use. To characterize breathing procedures, we track nasal airflow through computational fluid dynamics modeling, which requires the input of patient-specific minute ventilation (MV). However, there is currently no consistent quantification of breathing rates under CRS, and our objective is to ascertain the relevance of allometric MV prediction for healthy people, in a CRS population.

Study Design: Prospective observational study

Methods: Informed consent was obtained from 18 CRS patients (10 males, 8 females; 24-73 years) without nasal polyps, with no prior nasal surgery history, who failed maximal medical therapy and elected functional endoscopic sinus surgery. Pre-surgery breathing parameters were recorded via respiratory inductance plethysmography, using a vest-like patient garment (LifeShirt® system from VivoMetric, San Diego, CA). Measurements were corrected for recording awareness.

Results: A generic multi-term allometric function of body mass is proposed, with the extra terms accounting for CRS-related inconsistencies. Error minimization analysis reveals an optimal leading order similar to published equations for healthy individuals. For this CRS cohort, the model demonstrates comparable MV estimates for males ($SD = 2.28$) and females ($SD = 2.47$) over the estimates ($SD = 2.21$ for males, $SD = 2.57$ for females) using published allometric relations for healthy population.

Introduction

- **Predictive Minute Ventilation (MV) Formulation for CRS patients**
  - **Current *state-of-art*: Allometric formulations for healthy subjects**
  - **Goal: Revised allometric formulation, dependent on body weight, for CRS population**

Methods and Materials

- **Cohort**
  - **18 patients with history of CRS – 10 males, 8 females**
  - **Age range 24 – 73 years**
  - **Pre-surgery population**
- **Measurement**
  - **Portable respiratory inductive plethysmograph (LifeShirt®, VivoMetric, San Diego, CA)**
  - **Tracks breathing through chest volume expansion-relaxation trends**
- **Analysis**
  - **Allometric scaling**
  - **Dissipative term to account for CRS effects on breathing**
  - **Generic assumed equation for minute volume breathing:**

$$\dot{V} = A_1 W^{N_1} \boxed{- A_2 W^{N_2}} \longrightarrow \text{Dissipative term}$$

  - **$\dot{V}$ = Minute ventilation (Liters/min); W = Body Weight (kg)**
    A_1, A_2 = Cofactors; N_1, N_2 = Indices

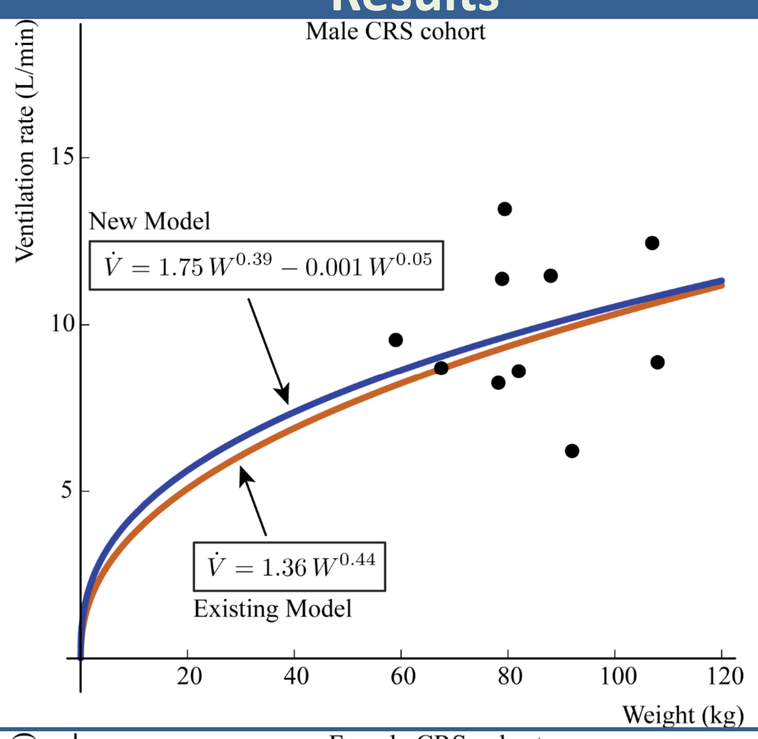
Table 1. CRS Cohort

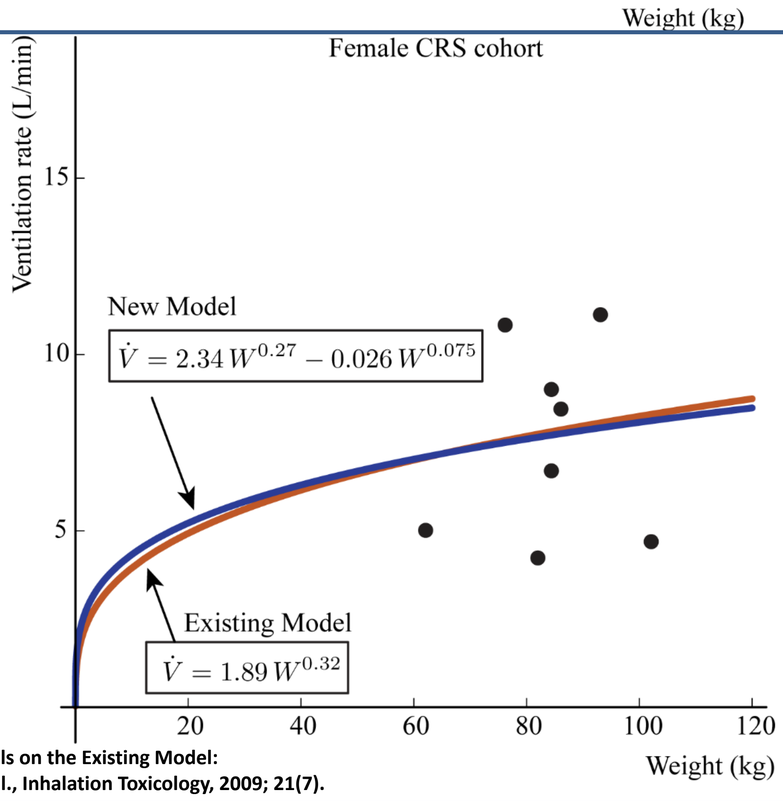
ID	Gender	Age (years)	Ethnicity	Height (cm)	Weight (kg)
1.	F	70	White	165	86.1
2.	M	70	White	165	67.5
3.	M	30	White	182	78.2
4.	F	24	White	169	93.1
5.	M	41	White	186.7	88.0
6.	F	62	White	161.3	84.4
7.	F	47	White	147	62.1
8.	F	69	White	169	76.2
9.	M	61	White	183	108.4
10.	M	46	White	183	79.4
11.	M	73	African-American	170	59.0
12.	M	72	White	183	78.9
13.	M	66	White	170.2	107.0
14.	F	68	African-American	168	84.4
15.	M	52	White	175	82.0
16.	M	28	White	180	92.0
17.	F	37	White	160	102.1
18.	F	42	African-American	170	82.0

Some salient points

- **MV measurements corrected by a multiplication factor of 0.9424, to account for awareness of the breathing-recording.** **(For more details: see Han et al., Eur. Respir. J., 1997)**
- **Mathematical strategy for the limited-sized cohort:**
  - Current CRS RO1 cohort: 18 patients (10 males, 8 females)
  - Number of unknowns in the model equation: 4 (A_1, A_2, N_1, N_2)
  - With (10+8) pairs of ($\dot{V}$, W):
    10 distinct allometric equations for males, 8 distinct equations for females
  - To solve for the 4 unknowns:
    10C4 = 210 sets of 4 equations for males, 8C4 = 70 sets of 4 equations for females
  - A_1, A_2, N_1, N_2 are averaged from these 210 (males) and 70 (females) solution sets

Results





For more details on the Existing Model:
See Garcia et al., Inhalation Toxicology, 2009; 21(7).

Conclusions

Standard Deviation (in L/min) of the MV measurements with respect to model values

	New CRS-specific Predictive Model	Existing Model (based on healthy population)
Male	2.28	2.21
Female	2.47	2.57

- **The new model predictions are comparable to the existing model, albeit with a slight improvement in the female cohort prediction.**
- **New predictive equations suggest minor CRS-related breathing dissipative effects in males; however that factor seems to be more significant in females.**

Future Directions

- **We will be recruiting 12 more CRS patients under our study (with the main goal of optimizing sprayed drug delivery techniques for CRS targets).**
- **The 30-patient cohort will assist in improving the statistical robustness of this predictive allometric MV model.**

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Abbreviations used: MV = Minute Ventilation, CRS = Chronic Rhinosinusitis

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