Reference Values for Volumetric Capnography in Spontaneously Breathing Individuals

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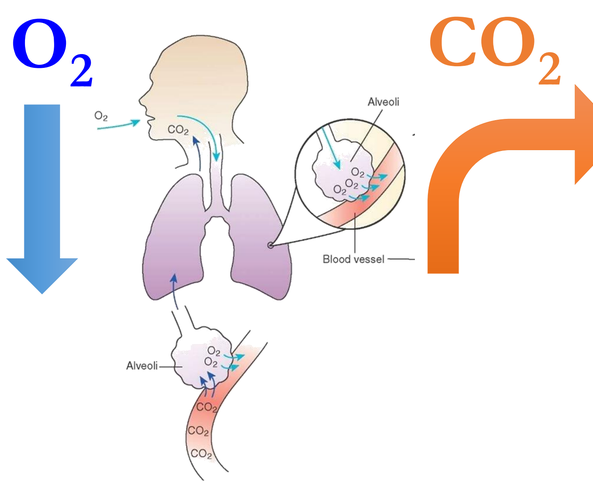
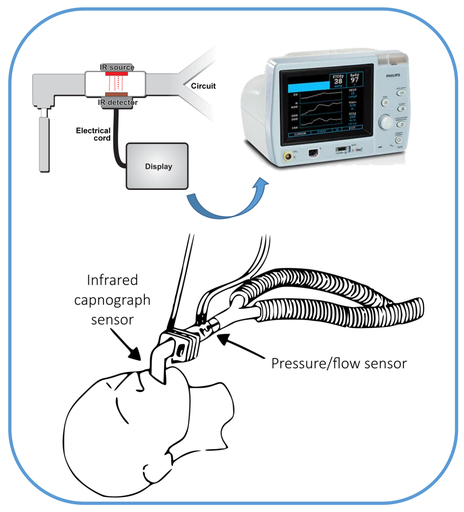
Background

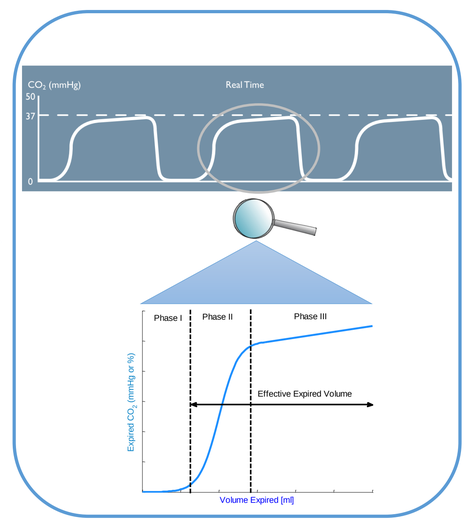
- Capnography is a non-invasive technique for monitoring the CO_2 concentration in the exhaled breath. The CO_2 waveform (capnogram) measured as a function of time or volume reflects respiratory dynamics
- The capnogram is commonly used to monitor mechanically ventilated patients or in emergency care where the waveform is assessed visually
- Automatically derived waveform parameters may enable capnography-based applications for spontaneously breathing individuals



Respiratory Physiology



Monitoring Technology



Waveform (Capnogram)

Study Aims

- To determine reference values for parameters derived automatically from volumetric capnograms of spontaneously breathing subjects
- To assess the inter-measurement variability of the derived parameters

Study design

Measurements of spontaneous breathing were acquired from healthy subjects (**Table 1**) using a respiratory profile monitor (NM3, Philips Healthcare) including a mainstream CO_2 sensor (**Figure 1**). Each subject was measured in semi-recumbent position for a duration of 10 minutes. Measurements were repeated 10 times on consecutive days.

Figure 1. Respiratory profile monitor (Philips NM3)

10 Subjects ✖ 10 Repetitions

Age [years]	Height [cm]	Weight [kg]	BMI [kg/cm^2]
26 ± 3	168.8 ± 8.58	69.1 ± 8.69	24.18 ± 1.89

Table 1. Subject characteristics presented as mean ± standard deviation.

Capnography-derived parameters

- Morphologic features of the volumetric capnogram were determined breath-by-breath using algorithms implemented in MATLAB®
- The slopes of phases II and III (S_{II}, S_{III}) were computed by linear least-squares regression on the corresponding segment of the waveform (**Figure 2**)
- The volume of airway deadspace (VD_{aw}) was computed using Fowler's method of equal area triangles (**Figure 3**) [1]

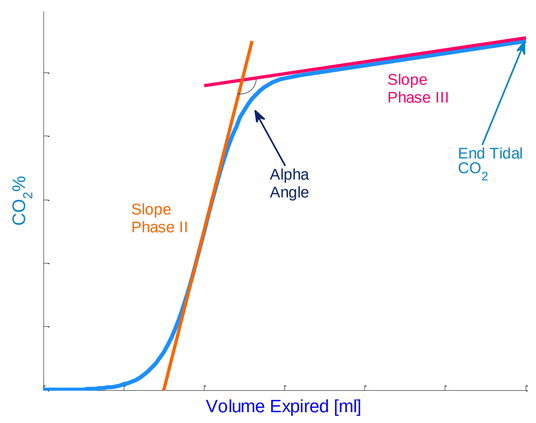


Figure 2. Single breath volumetric capnogram and morphologic features

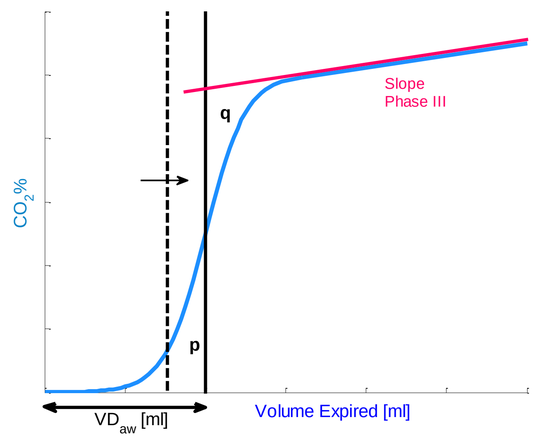


Figure 3. Fowler's method for the quantitative assessment of VD_{aw}

Data Analysis

Reference values for capnography-derived parameters were determined on the pooled measurements of all subjects. The inter-measurement variability was assessed using the coefficient of variation (C_V)

Results

- The reference values determined in this study for automatically derived parameters from volumetric capnograms are presented in **Table 2** are expressed in different measurement units used in literature to allow comparison with other studies of volumetric capnography
- The value of the α Angle is sensitive to the measurement unit used for computing S_{III} and S_{II} and consequently it increases by ~10° if the slopes are expressed in mmHg/ml, compared to the value reported in **Table 2**, where the α Angle is based on slopes expressed in %/L
- Our results are in agreement with the results from previous studies investigating spontaneous breathing in healthy subjects [2,3]
- In addition to previous studies, we determined the normal inter-measurement variability of respiratory parameters

Metric	V_{exp}	VD_{aw}	$ETCO_2$	S_{III}			S_{II}			α Angle
	ml	ml	mmHg	%/L	mmHg/ml	°	%/L	mmHg/ml	°	°
Mean ± SD	549 ± 156	135 ± 29	41 ± 3.2	1.81 ± 1.14	0.013 ± 0.008	57 ± 11.82	53.5 ± 24.12	0.4 ± 0.18	89 ± 0.28	148 ± 11.86
Median	521.9	131.2	41	1.56	0.011	57.33	51.06	0.38	88.87	148.50
Q1-Q3	184	49	5	0.98	0.0080	15.72	19.64	0.14	0.42	15.64
C_V (%)	13.56	5.21	3.98	22.80	23.04	10.02	8.065	7.96	0.09	3.73

Table 2. Reference values for volumetric capnography-derived parameters in healthy subjects and the corresponding inter-measurement coefficient of variation (C_V).

Conclusions

The reference values determined in this study for healthy individuals may be compared in further studies to values of patients with respiratory dysfunctions. Inter-measurement variations outside the normal range determined in this study may indicate abnormal respiratory dynamics.

References

[1] W. S. Fowler, Lung function studies. II. The respiratory dead space, Am. J. Physiol. Content, vol. 154, no. 3, pp. 405–416, 1948.
[2] G. Tusman et al. "Reference values for volumetric capnography-derived non-invasive parameters in healthy individuals," J. Clin. Monit. Comput., 27(3), 281–288, Feb. 2013.
[3] G. Tusman et al. "Reference Values For Non-Invasive Volumetric Capnographic Parameters In Awake And Anesthetized Humans," Am J Respir Crit Care Med, vol. 185, p. A1663, 2012.

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