
# Dead-Space Calculations

For Vyntus™ CPX and SentrySuite™ Software

vyaire™ MEDICAL

# Dead-Space Calculations

In our SentrySuite™ – Cardiopulmonary Exercise Testing (CPET)-program, three different dead-space calculations: $VD_f$, $VD_c$ and $VD_e$ are available. These are the dead-spaces (normally expressed in mL) and calculated according to different publications from the literature. The relative dead-spaces $VD_x/VT$ are often also reported as $VD_x/VE$. The meaning of both is the same; both are expressing the relative dead-space ventilation (either per breath or per minute ventilation).

## Note 1

Per customer requests, we implemented all three published values [1,2,3] in our SentrySuite Software. Nevertheless Lewis [2] and Wasserman [1] recommend not to use $VD_e$ or $VD_c$ but only use the $VD_f$ and $VD_f/VT$-values: In case of inhomogeneity or gas exchange problems, $VD_c$ and $VD_e$ provide wrong false values (they seem to be more or less acceptable for healthy subjects (with a very low physiological dead-space), but show unreliable “healthy” values in different diseases due to increased alveolar dead-space).

## Note 2

During CPET, the subject is connected via a mouthpiece or a face mask with the volume sensor of the system. Therefore, the determined dead-space $VD_{determined}$ will be the sum of

$$VD_{determined} = VD_{patient} + VD_{system}$$

with

$$VD_{system} = VD_{mask} + VD_{volume\text{-}sensor}$$

and the patient’s dead-space must be corrected by the system dead-space:

$$VD_{patient} = VD_{determined} - VD_{mask} - VD_{volume\text{-}sensor}$$

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Therefore, it is recommended to select the used mask (or mouthpiece) in SentrySuite, so that the system can subtract the correct $VD_{system}$ from the calculated $VD_{determined}$ (the $VD_{volume\text{-}sensor}$ = 30 mL is automatically considered as well).

## Note 3

Please consider, that the following parameters (and only these) are affected by the system dead-space $VD_{system}$ and may be not correct, if the $VD_{system}$ is not selected properly:

- The dead spaces: $VD_f$, $VD_e$, $VD_c$
- The relative dead-spaces: $VD_f/VT$, $VD_e/VT$, $VD_c/VT$
- And the ventilatory equivalents: $EqO_2$, $EqCO_2$

## Calculation formulas:

### 1. $VD_f$ / VT:

The **f**unctional (also named as physiological) dead-space can be calculated according to Bohr's formula out of arterial $CO_2$ (**$PaCO_2$**) and mixed expired $CO_2$ (**$PECO_2$**):

$$VD_f/VT = ((PaCO_2 - PECO_2) / PaCO_2 - VD_s/VT) * 100 \quad [\%]$$

with

| | | |
|---|---|---|
| $PaCO_2$: | arterial $CO_2$-pressure | [mmHg] |
| $PECO_2$ | = $FECO_2$ * (BP-47) / 100 | [mmHg] |
| FECO2: | mixed expired CO2-concentration | [%] |
| BF: | breathing frequency | [1/min] |
| BP: | bar pressure | [mmHg] |
| VT: | tidal volume | [L] |
| $VD_s$: | system dead-space (mask, mouthpiece etc.) | [L] |

# Dead-Space Calculations

## 2. $VD_e$ / VT:

As $PaCO_2$ is in healthy subjects - due to low alveolar dead-space - very close to end-tidal $CO_2$ ($PETCO_2$), the "**e**nd-tidal" (or **e**stimated) dead-space may be calculated by using **$PETCO_2$** instead of $PaCO_2$

$$VD_e/VT = ((\mathbf{PETCO_2} - \mathbf{PECO_2}) / \mathbf{PETCO_2} - VDs/VT) * 100 \quad [\%]$$

| with | | |
|---|---|---|
| $PECO_2$ | = $FECO_2$ * (BP-47) / 100 | [mmHg] |
| $PETCO_2$ | = $FETCO_2$ * (BP-47) / 100 | [mmHg] |
| $FECO_2$: | mixed expired $CO_2$-concentration | [%] |
| BF: | breathing frequency | [1/min] |
| BP: | bar pressure | [mmHg] |
| VT: | tidal volume | [L] |
| $VD_s$: | system dead-space (mask, mouthpiece etc.) | [L] |

## 3. $VD_c$ / VT:

As the end-tidal values for $CO_2$ depend on the tidal volume (e.g. underestimated at low tidal volumes and overestimated at high VT), Jones [3] suggests to **c**alculate the arterial $CO_2$ ($PaCO2$**c**) from end-tidal $CO_2$ and tidal volume and use this value for calculating the dead-space:

$$VD_c/VT = ((\mathbf{PaCO_{2c}} - \mathbf{PECO2}) / \mathbf{PaCO_{2c}} - VD_s/VT) * 100 \quad [\%]$$

| with | | |
|---|---|---|
| $PaCO_{2c}$ | = 5.5 + 0.90 x $PETCO_2$ – 2.1 x VT | [mmHg] |
| $PECO_2$: | = $FECO_2$ * (BP-47) / 100 | [mmHg] |
| $PETCO_2$: | = $FETCO_2$ * (BP-47) / 100 | [mmHg] |
| $FECO_2$: | mixed expired $CO_2$-concentration | [%] |
| BF: | breathing frequency | [1/min] |
| BP: | bar pressure | [mmHg] |
| VT: | tidal volume | [L] |
| $VD_s$: | system dead-space (mask, mouthpiece etc.) | [L] |

# Dead-Space Calculations

## System dead-spaces ($VD_s$):

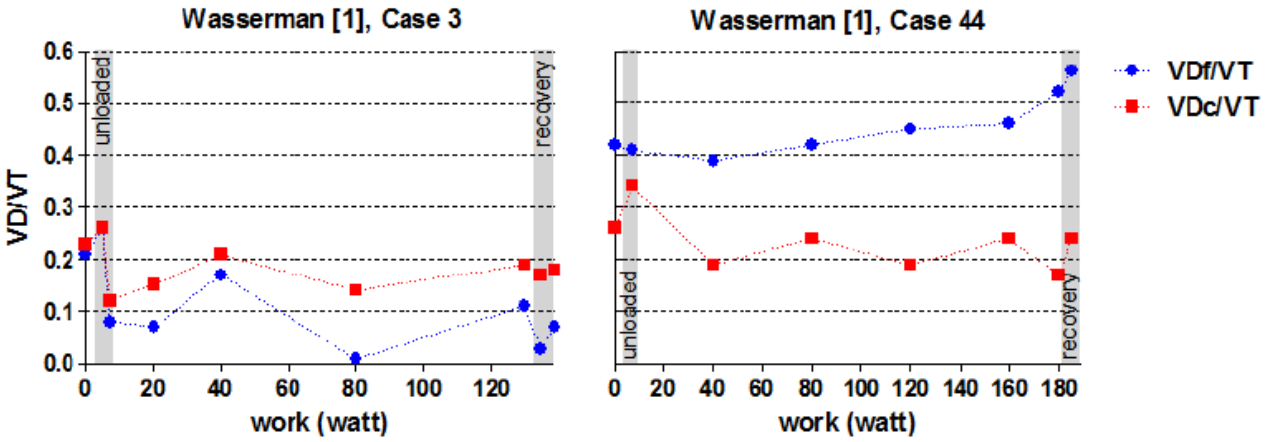
The system dead-space ($VD_s$) depends on the different parts (mask, mouthpiece, saliva pump, etc.) used during the measurement. The dead space of the face masks only can be estimated, as it depends both on the shape of the face (size of the nose) as well as from the efficiency of the equilibration of the expired gas in the mask itself.
The following table gives an overview about the $VD_s$ used in SentrySuite:
(Recommended $VD_s \approx$ Total $VD_s$ * estimated effective [%] + $VD_{TV\text{-}adaptor}$)

| Mask | Article no. | Total VDs (mL) (Manufac.) | estimated effective (%) | estimated effective (mL) | TV-Adapter (Vyntus™ CPX) | Total Mask (Vyntus CPX) | Recomm. Total for Vyntus CPX |
|---|---|---|---|---|---|---|---|
| Combitox mask | 982006 | 115 | 75% | 86 | 5 | 91 | 90 |
| 8900 Series HR Pediatric large | 982078 | 31,5 | 95% | 30 | 5 | 35 | 35 |
| 8900 Series HR Adult small | 982002 | 40,2 | 95% | 38 | 5 | 43 | 40 |
| 8900 Series HR Adult medium | 982149 | 46,7 | 95% | 44 | 5 | 49 | 45 |
| 8900 Series HR Adult large | 982003 | 49,1 | 95% | 47 | 5 | 52 | 50 |
| 7400 Series HR Petite (P) | 982167 | 53 | 90% | 48 | 5 | 53 | 50 |
| 7400 Series HR Extra small | 982163 | 62 | 90% | 56 | 5 | 61 | 60 |
| 7400 Series HR Small | 982164 | 73 | 90% | 66 | 5 | 71 | 70 |
| 7400 Series HR Medium | 982165 | 97 | 90% | 87 | 5 | 92 | 90 |
| 7400 Series HR Large | 982166 | 114 | 90% | 103 | 5 | 108 | 105 |
| 7450 V2 Series HR Petite (P) | V-982188 | 78 | 85% | 66 | 5 | 71 | 70 |
| 7450 V2 Series HR Extra small | V-982187 | 88 | 85% | 75 | 5 | 80 | 80 |
| 7450 V2 Series HR Small (S) | V-982184 | 99 | 85% | 84 | 5 | 89 | 90 |
| 7450 V2 Series HR Medium (M) | V-982185 | 125 | 85% | 106 | 5 | 111 | 110 |
| 7450 V2 Series HR Large | V-982186 | 143 | 85% | 122 | 5 | 127 | 125 |
| 6450 V2 Series HR Petite (P) | V-982183 | 78 | 85% | 66 | 5 | 71 | 70 |
| 6450 V2 Series HR Extra small | V-982182 | 88 | 85% | 75 | 5 | 80 | 80 |
| 6450 V2 Series HR Small (S) | V-982177 | 99 | 85% | 84 | 5 | 89 | 90 |
| 6450 V2 Series HR Medium (M) | V-982178 | 125 | 85% | 106 | 5 | 111 | 110 |
| 6450 V2 Series HR Large (L) | V-982179 | 143 | 85% | 122 | 5 | 127 | 125 |
| | | | | | | | |
| Note: | Actual | | | | | | |
| | Obsolete | | | | | | |

# Dead-Space Calculations

## Comparing $VD_f$ and $VD_c$:

In addition, comparing the dead spaces with blood gas calculations ($VD_f$), it's even more obvious that $VD_c$ does not represent the correct $VD_{patient}$:




In a healthy subject (left, Case 3), $VD_c$/VT starts at normal values, but is overestimating at higher load, while in diseases (right, Case 44) $VD_c$/VT is strongly underestimating the patient's dead-space.

## Literature


(1) Wasserman K., Hansen J.E., Sue D.Y., Stringer W.W., Sietsema K.E., Sun X-G., Whipp B.J.
Principles of Exercise Testing and Interpretation 5th edition (2012)
Lippincott Williams & Wilkins
ISBN-13: 978-1-60913-899-8

(2) Lewis D.A., Sietsema K.E., Casaburi R., Sue D.Y.
Inaccuracy of Noninvasive Estimates of VD/VT in Clinical Exercise Testing
Chest 5_106 (1994)

(3) Jones N.L.
Clinical Exercise Testing
4th Edition, W.B. Saunders Company (1997)
ISBN: 0-7216-6511-x



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