Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot

srlf
SOCIÉTÉ DE RÉANIMATION DE LANGUE FRANÇAISE
www.srlf.org

Cliniques universitaires SAINT-LUC
UCLouvain BRUXELLES

Gestion de l’espace mort en pédiatrie

Dr Laurent houtekie

Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot

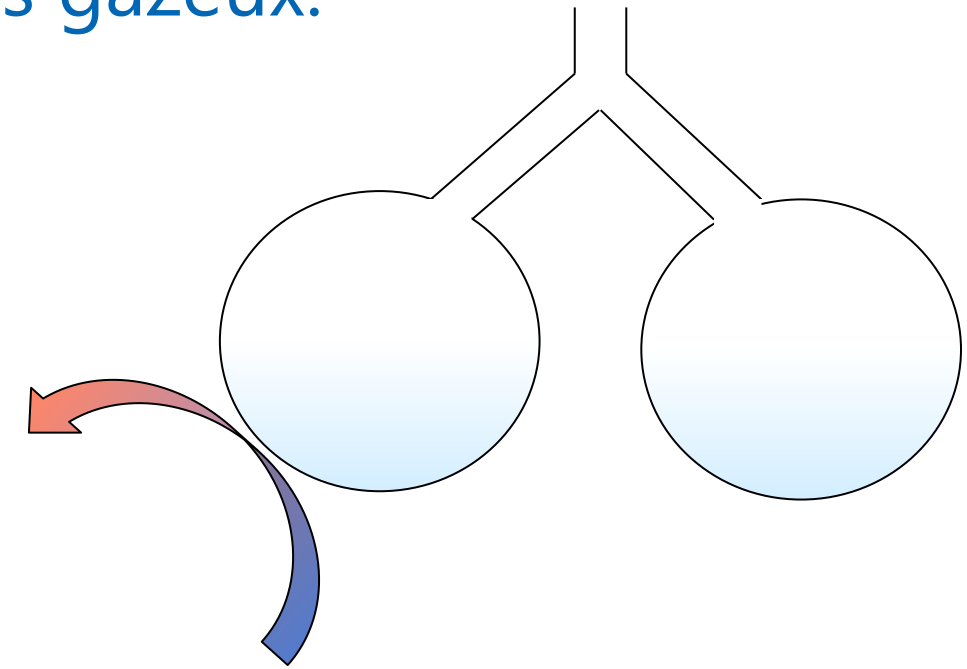
Cliniques universitaires SAINT-LUC
UCLouvain BRUXELLES

Orateur : Laurent HOUTEKIE, Bruxelles

- ☑ Je n'ai pas de lien d'intérêt potentiel à déclarer

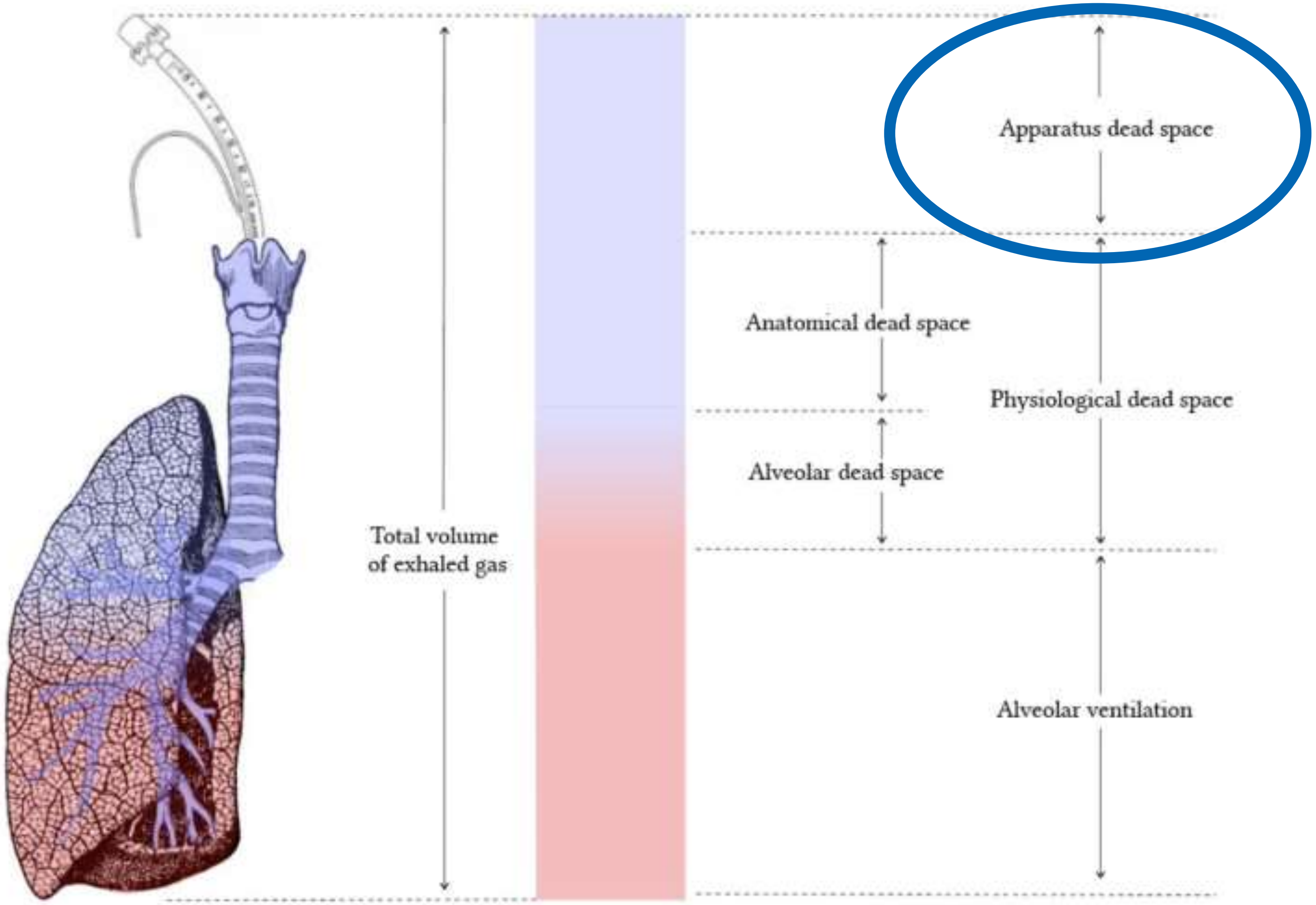
Définitions

L'espace mort correspond à l'ensemble des zones du système respiratoire qui sont ventilées mais non perfusées → elles ne participent donc pas aux échanges gazeux.



réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot

Définitions



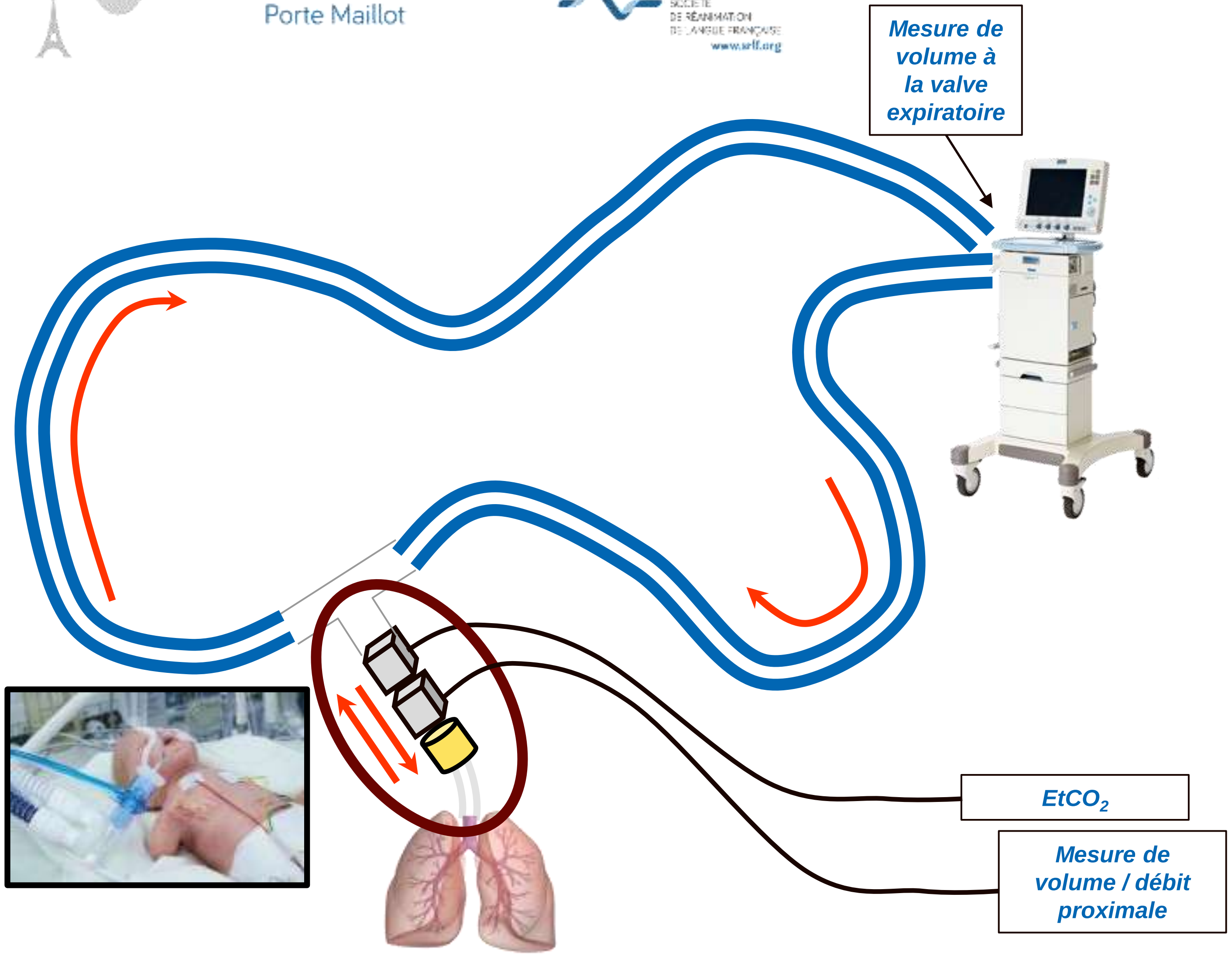
Derangedphysiology.com

Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot
srlf

Cliniques universitaires
SAINT-LUC
UCLouvain BRUXELLES

Circuit de ventilation



Exemples de volumes

55 mL

30 mL

Exemples de volumes

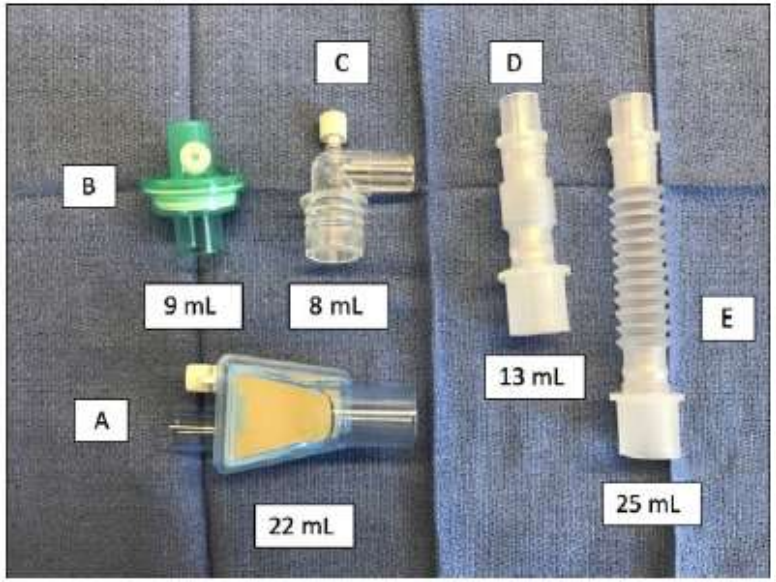


FIGURE 2 Apparatus commonly added to the breathing circuit that impacts dead space with associated dead space volumes. A, Small HME, B, Large HME, C, Elbow connection (Note: A, B, and C support gas sampling), D, Flexible connector contracted, E, Flexible connector expanded

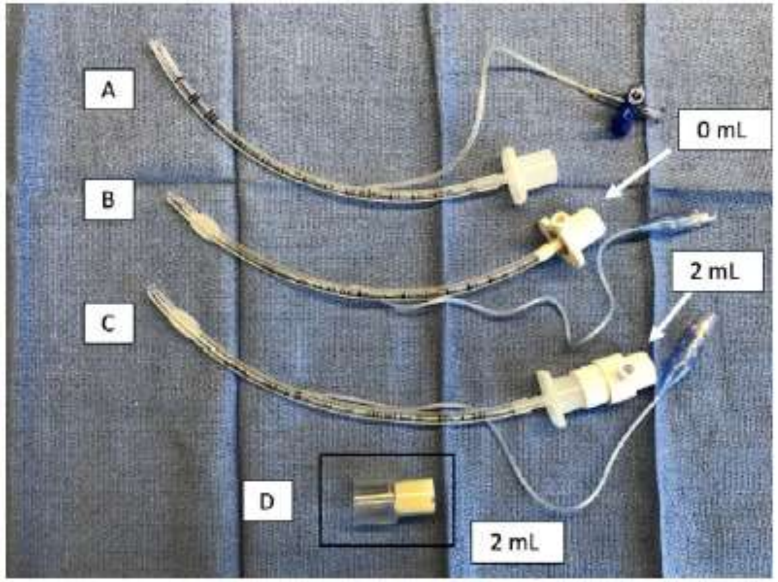


FIGURE 3 Examples of apparatus that can be used to minimize dead space in patients less than 5 kg. A, Uncuffed endotracheal tube with distal sampling port, B, Cuffed ETT with 15 mm connector replaced by sampling connector, C, Cuffed ETT with sampling adapter attached, 2 mL dead space added, and D, Nonsampling HME, dead space 2 mL

Pediatric Anesthesia. 2017;27:1185–1192.

Exemples de volumes

TABLE 1 Heat and moisture exchange products reviewed listed with sidestream capability, tidal volume (V_t) range, dead space volume, humidity in mg H_2O/L, and resistance in cm H_2O

Model	Sidestream	V_t range (mL)	Dead space (mL)	Humidity (mg H_2O/L)	Resistance (cm H_2O)
Hudson RCI Humid-Vent (HV)					
HV mini	N	15-50	2.4	30 @ V_t 20	0.9 @ 10 LPM
HV 1	N	50-600	10	30.5 V_t 200	0.3 @ 20 LPM
HV 1 port	Y	50-600	14	30.5 V_t 200	0.3 @ 20 LPM
Covidien DAR					
DAR ped-neonatal HME/filter small	Y	30-100	10	30 @ V_t 50	0.6 @ 5 LPM
DAR infant-ped HME/filter small	Y	75-300	31	32.3 @ V_t 250	1.6 @ 20 LPM
Carefusion HME					
Infant HCH	N	10-50	2	31.7 @ V_t 500	1.1 @ 15 LPM
Small volume filtered w/port	Y	70-600	22	25.9 @ V_t 500	1 @ 15 LPM
Medline					
Neonatal straight HME filter	N	> 10	2	32 @ V_t 25	1.5 @ 60 LPM
Neonatal angled HME filter	Y	> 45	14	31 @ V_t 50	0.8 @ 7.5 LPM
Neonatal angled HME filter	Y	> 45	14	31 @ V_t 50	0.6 @ 7.5 LPM
Teleflex					
Gibeck Humid-Vent filter pedi	Y	50-250	13	30 @ V_t 100	1.4 @ 20 LPM
Humid-Vent mini	N	15-50	2.4	30 @ V_t 20	0.9 @ 10 LPM
Humid-Vent 1	N	50-600	10	30.5 @ V_t 200	0.3 @ 20 LPM
Humid-Vent 1 Port	Y	50-600	14	30.5 @ V_t 200	0.3 @ 20 LPM
AQUA+ N	N	10-50	2	30 @ V_t 25	1.8 @ 15 LPM
AQUA+ T	N	75-1K	15	24 @ V_t 500	0.2 @ 60 LPM
Intersurgical					
Clear-Therm MicroHMEF w/elbow	Y	>25	17	27 @ V_t 25	1.2 @ 11 LPM
Clear-Therm MicroHMEF (no elbow)	Y	>25	11	27 @ V_t 25	1 @ 11 LPM
Clear-Therm MiniHMEF w/elbow	Y	>75	34	32 @ V_t 250	2 @ 30 LPM
Clear-Therm MiniHMEF (no elbow)	Y	>75	28	32 @ V_t 250	1.6 @ 30 LPM
Inter-Therm Mini Pediatric HMEF	Y	>75	28	30 (no V_t reported)	2.1 @ 30 LPM
Inter-Therm Mini HMEF angled	Y	>75	29	30 (no V_t reported)	2.2 @ 30 LPM
Drager					
TwinStar 10A	Y	25-200	10	37.6 @ V_t 50	1.0 @ 10 LPM
TwinStar 8	Y	25-200	8	37.9 @ V_t 50	1.6 @ 10 LPM
HumidStar 10A	Y	25-200	10	37.6 @ V_t 50	0.2 @ 10 LPM
HumidStar 2	N	10-50	2	37.6 @ V_t 50	1.1 @ 10 LPM
TwinStar 25	Y	75-500	25	38.2 @ V_t 250	1.8 @ 20 LPM
HumidStar 25	Y	75-500	25	37.8 @ V_t 250	0.3 @ 20 LPM
Portex					
Neonatal HME straight	N	>10	3	32 @ V_t 25	0.9 @ 5 LPM
HME pedi w/gas port angled	Y	>45	13	31 @ V_t 50	0.2 @ 10 LPM

V_t, tidal volume; LPM, liters per minute. Note the increase in dead space associated with sidestream sampling capability

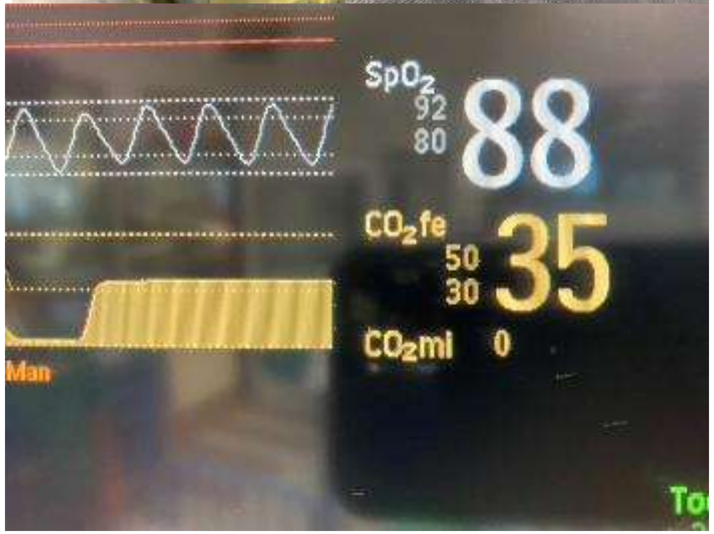
Pediatric Anesthesia. 2017;27:1185–1192.

Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot
srlf
SOCIETE DE REANIMATION DE LANGUE FRANÇAISE
www.srlf.org

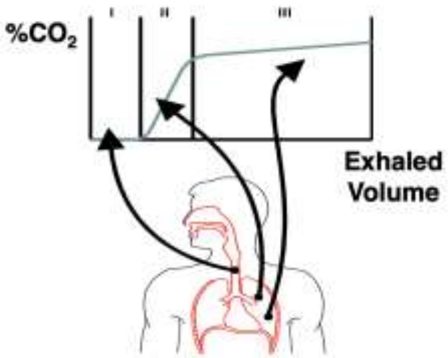
Cliniques universitaires
SAINT-LUC
UCLouvain BRUXELLES

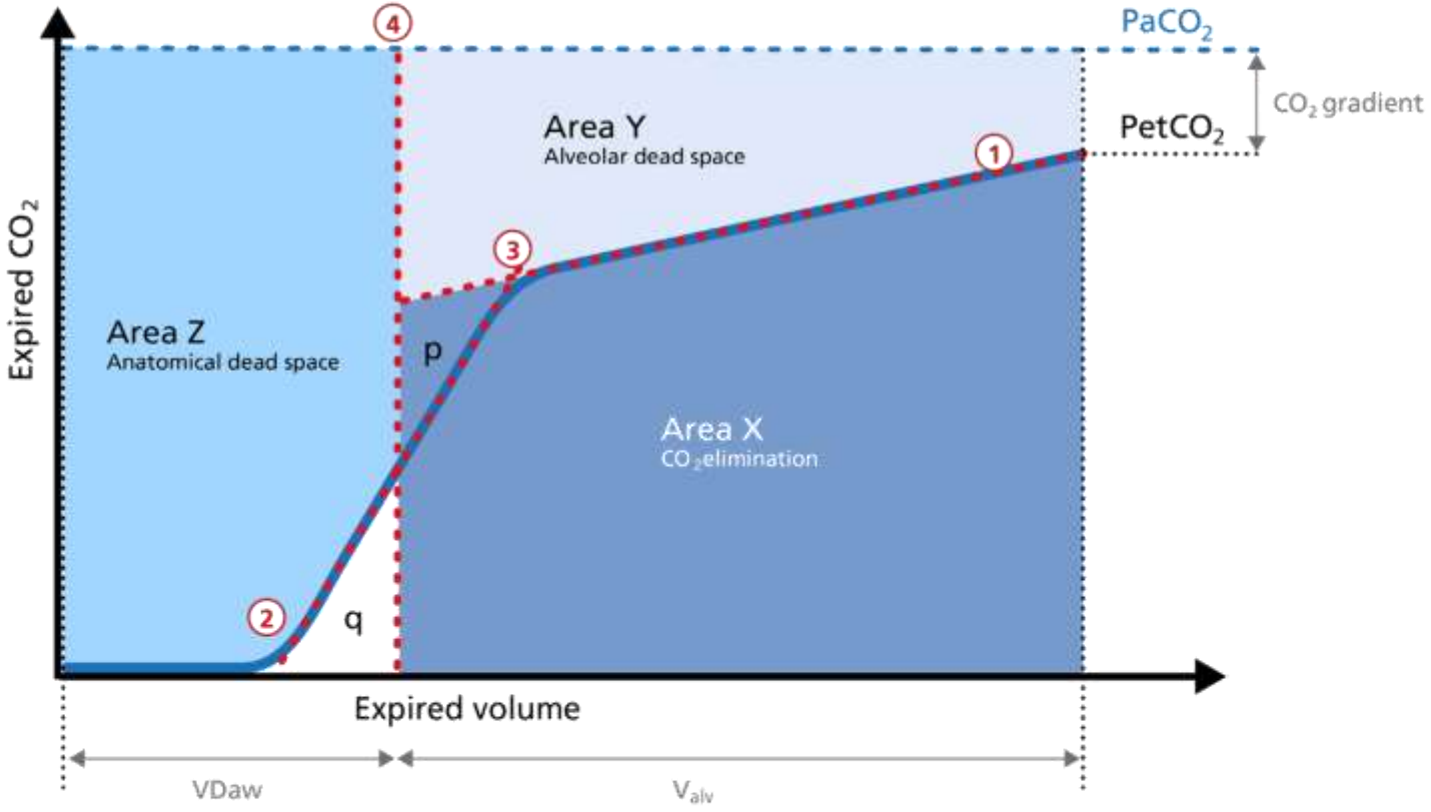
Influence sur la ventilation



NB : cardiopathie cyanogène

Capnographie volumétrique





Hamilton.com

Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot
srlf SOCIÉTÉ DE RÉANIMATION DE LANGUE FRANÇAISE www.srlf.org

Cliniques universitaires SAINT-LUC UCLouvain BRUXELLES

Prématurés

CLINICAL RESEARCH ARTICLE OPEN

Physiological dead space and alveolar ventilation in ventilated infants

Emma Williams[1,2], Theodore Dassios[1,3], Paul Dixon[4] and Anne Greenough[1,2,5]

BACKGROUND: Dead space is the volume not taking part in gas exchange and, if increased, could affect alveolar ventilation if there is too low a delivered volume. We determined if there were differences in dead space and alveolar ventilation in ventilated infants with pulmonary disease or no respiratory morbidity.
METHODS: A prospective study of mechanically ventilated infants was undertaken. Expiratory tidal volume and carbon dioxide levels were measured. Volumetric capnograms were constructed to calculate the dead space using the modified Bohr–Enghoff equation. Alveolar ventilation (V_A) was also calculated.
RESULTS: Eighty-one infants with a median (range) gestational age of 28.7 (22.4–41.9) weeks were recruited. The dead space [median (IQR)] was higher in 35 infants with respiratory distress syndrome (RDS) [5.7 (5.1–7.0) ml/kg] and in 26 infants with bronchopulmonary dysplasia (BPD) [6.4 (5.1–7.5) ml/kg] than in 20 term controls with no respiratory disease [3.5 (2.8–4.2) ml/kg, $p < 0.001$]. Minute ventilation was higher in both infants with RDS or BPD compared to the controls. V_A in infants with RDS or BPD was similar to that of the controls [$p = 0.54$].
CONCLUSION: Prematurely born infants with pulmonary disease have a higher dead space than term controls, which may influence the optimum level during volume-targeted ventilation.

Pediatric Research (2022) 91:218–222; https://doi.org/10.1038/s41390-021-01388-8

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot

Cliniques universitaires SAINT-LUC
UCLouvain BRUXELLES

Prématurés

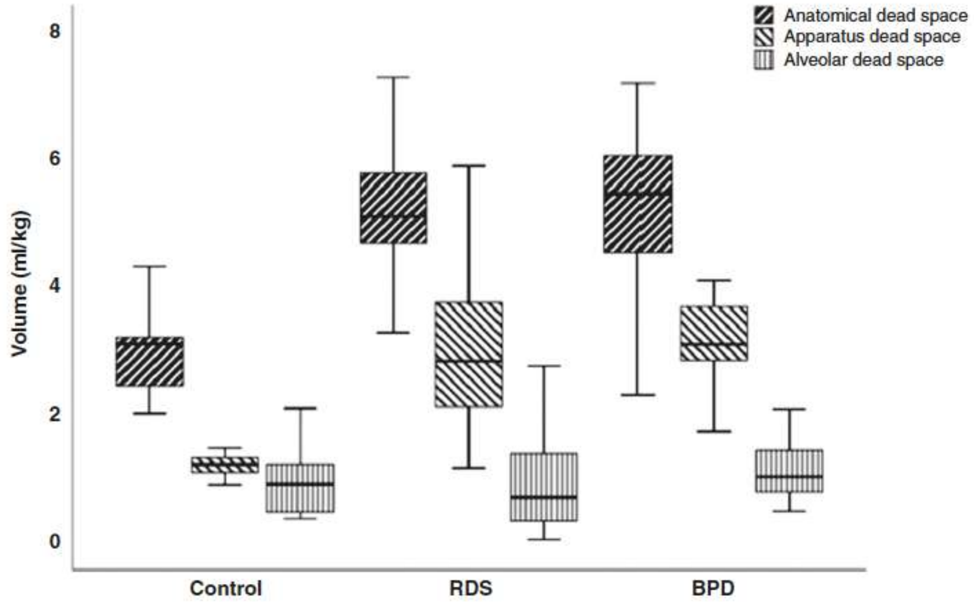


Table 2. Dead space and alveolar ventilation parameter of infants in each group.

	Control ($n = 20$)	RDS ($n = 35$)	BPD ($n = 26$)	p value	Control–RDS	Control–BPD	RDS–BPD
Physiological dead space (ml/kg)	3.5 (2.8–4.3)	5.7 (5.1–7.0)	6.4 (5.1–7.5)	<0.001	<0.001	<0.001	0.372
Total anatomical dead space (ml/kg)	2.7 (2.4–3.2)	5.1 (4.7–5.9)	5.4 (4.4–6.1)	<0.001	<0.001	<0.001	0.811
Apparatus dead space (ml/kg)	1.2 (1.1–1.4)	2.8 (2.0–3.8)	3.1 (2.8–3.7)	<0.001	<0.001	<0.001	0.353
Anatomical minus apparatus dead space (ml/kg)	1.6 (1.1–2.2)	2.4 (1.5–3.2)	2.0 (1.4–2.9)	0.171			
Alveolar dead space (ml/kg)	0.5 (0.3–1.2)	0.7 (0.2–1.5)	1.0 (0.8–1.4)	0.018	0.506	0.006	0.030
Tidal volume (ml/kg)	6.4 (5.4–7.6)	8.5 (6.6–9.6)	8.2 (7.5–10.3)	0.009	0.008	0.004	0.745
Dead space to tidal volume ratio	0.52 (0.43–0.62)	0.75 (0.64–0.81)	0.77 (0.71–0.82)	<0.001	<0.001	<0.001	0.220
Minute ventilation (ml/kg/min)	239 (193–378)	369 (311–450)	403 (321–505)	0.003	0.002	0.001	0.580
Alveolar ventilation (ml/kg/min)	111 (81–159)	83 (66–137)	82 (62–133)	0.537			

Data presented as median with interquartile range (IQR) in brackets.

Soins Intensifs Pédiatriques

réanimation 2022
PARIS 22-24 JUIN
Palais des Congrès de Paris
Porte Maillot

srlf
SOCIÉTÉ DE RÉANIMATION DE LANGUE FRANÇAISE
www.srlf.org

Cliniques universitaires SAINT-LUC
UCLouvain BRUXELLES

Prématurés

CLINICAL RESEARCH ARTICLE **OPEN**

Physiological dead space and alveolar ventilation in ventilated infants

Emma Williams[1,2], Theodore Dassios[1,3], Paul Dixon[4] and Anne Greenough[1,2,5]

BACKGROUND: Dead space is the volume not taking part in gas exchange and, if increased, could affect alveolar ventilation if there is too low a delivered volume. We determined if there were differences in dead space and alveolar ventilation in ventilated infants with pulmonary disease or no respiratory morbidity.
METHODS: A prospective study of mechanically ventilated infants was undertaken. Expiratory tidal volume and carbon dioxide levels were measured. Volumetric capnograms were constructed to calculate the dead space using the modified Bohr–Enghoff equation. Alveolar ventilation (V_A) was also calculated.
RESULTS: Eighty-one infants with a median (range) gestational age of 28.7 (22.4–41.9) weeks were recruited. The dead space [median (IQR)] was higher in 35 infants with respiratory distress syndrome (RDS) [5.7 (5.1–7.0) ml/kg] and in 26 infants with bronchopulmonary dysplasia (BPD) [6.4 (5.1–7.5) ml/kg] than in 20 term controls with no respiratory disease [3.5 (2.8–4.2) ml/kg, $p < 0.001$]. Minute ventilation was higher in both infants with RDS or BPD compared to the controls. V_A in infants with RDS or BPD was similar to that of the controls [$p = 0.54$].
CONCLUSION: Prematurely born infants with pulmonary disease have a higher dead space than term controls, which may influence the optimum level during volume-targeted ventilation.

Pediatric Research (2022) 91:218–222; https://doi.org/10.1038/s41390-021-01388-8

Recommendations

Optimal management of apparatus dead space in the anesthetized infant

Michael R. King[1] | **Jeffrey M. Feldman**[2]

[1] Ann and Robert H. Lurie Children's Hospital of Chicago and Northwestern University Feinberg School of Medicine, Chicago, IL, USA

[2] The Children's Hospital of Philadelphia and the University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, USA

Correspondence
Dr Michael R. King, Department of Pediatric Anesthesiology, Ann and Robert H. Lurie Children's Hospital, Chicago, IL, USA.
Email: mrking1@gmail.com

Funding information
This study was funded by Departmental Resources.

Section Editor: Dr Mark Thomas

Summary

Mechanical ventilation of the anesthetized infant requires careful attention to equipment and ventilator settings to assure optimal gas exchange and minimize the potential for lung injury. Apparatus dead space, defined as dead space resulting from devices placed between the endotracheal tube and the Y-piece of the breathing circuit, is the primary source of dead space controlled by the clinician. Due to the small tidal volumes required by infants and neonates, it is easy to create excessive apparatus dead space resulting in unintended hypercarbia or increased minute ventilation in an effort to achieve a desirable PCO_2. The goal of this review was to evaluate the apparatus that are commonly added to the breathing circuit during anesthesia care, and develop recommendations to guide the clinician in selecting apparatus that are best matched to the clinical goals and the patient's size. We include specific recommendations for apparatus that are best suited for different size pediatric patients, with a particular focus on patients <5 kg.

KEYWORDS
capnography, general anesthesia, humidifiers, mechanical ventilation, respiratory dead space, respiratory physiology phenomena

Pediatric Anesthesia. 2017;27:1185–1192.

Recommendations

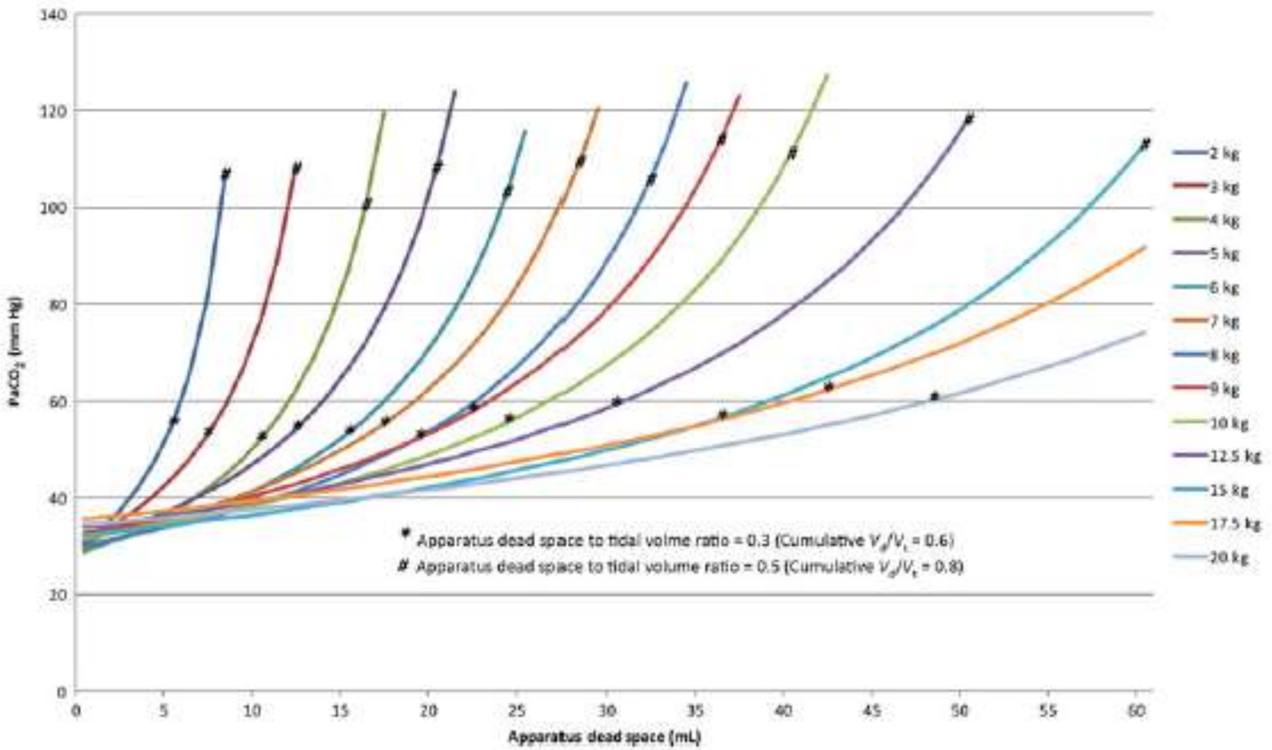


FIGURE 1 Graph of P_aCO_2 values for variable apparatus dead space and variable patient weight. Apparatus dead space to tidal volume ratios of 0.3 and 0.5 that correspond to cumulative V_d/V_t ratios of 0.6 and 0.8, respectively, are depicted. (From Pearsall and Feldman[4])

Pediatric Anesthesia. 2017;27:1185–1192.

Recommendations

TABLE 2 Example equipment choices for minimal, low, and normal dead space goals

	Airway	Humidification	Gas sampling	Bacterial filter	Connectors	Estimated minimum apparatus dead space (mL)
Minimum dead space, up to 5 kg or significant lung disease	Uncuffed sampling ETT	Active (0 mL)	ETT (0 mL additional)	Expiratory and/or inspiratory limb (0 mL)	None (0 mL)	0
	Uncuffed ETT with sampling adaptor	Nonsampling HME (2 mL+)	ETT (0 mL additional)	Expiratory and/or inspiratory limb (0 mL)	None (0 mL)	2+
	Cuffed ETT	Active (0 mL)	Mainstream adapter or dedicated small volume attachment (1 mL+)	Expiratory and/or inspiratory limb (0 mL)	None (0 mL)	1+
	Cuffed ETT	Active (0 mL)	Pediatric sidestream sampling adapter (2 mL+)	Expiratory and/or inspiratory limb (0 mL)	None (0 mL)	2+
Low dead space, 5-15 kg	Cuffed ETT—consider Microcuff, trimmed	HME appropriately sized for tidal volume, with sidestream sampling (8 mL+)	Part of HME (0 mL additional)	Part of HME (0 mL additional)	None (0 mL)	8+
Normal dead space, >15 kg	Standard cuffed ETT	HME (9 mL+)	Part of HME (0 mL additional)	Part of HME (0 mL additional)	Elbow optional (8 mL+)	17+

Equipment dead space volumes are displayed with each option and assume use of the lowest dead space models available, with a plus sign denoting possibly higher values depending on the model. Dead space volume of endotracheal tubes varies with internal diameters and impact of trimming can be calculated. ETT, endotracheal tube; HME, heat and moisture exchanger.

Pediatric Anesthesia. 2017;27:1185–1192.

Recommandations

5 | SUMMARY/CONCLUSION

The impact of breathing circuit apparatus on total dead space volume is well known as is the increased ventilation requirements that result. Devices that add dead space should be selected with a consideration of the dead space volume imposed and the clinical benefit offered by the device. This review is intended to highlight the considerations involved with selecting breathing circuit apparatus and provide guidance for optimal selection. Ultimately, the risk to the individual patient of increasing dead space and the associated impact on ventilation requirements and arterial CO_2 needs to be considered when selecting breathing circuit components.

Pediatric Anesthesia. 2017;27:1185–1192.

Conclusion

- L'espace mort peut-être un composant important du volume mesuré/prescrit en ventilation mécanique.
- Cela est d'autant plus vrai que l'enfant est petit.
- On peut difficilement contrôler l'espace mort physiologique → importance du matériel utilisé!

Questions?