

REDEFINING VENTILATION

Flow-Controlled Ventilation (FCV®)

Evone®



We can ventilate so much better

REDEFINING VENTILATION

Flow-Controlled Ventilation (FCV®)

Ventivova Medical introduces **Evone®**, the first and unique mechanical ventilator that provides Full-Controlled Ventilation of the entire ventilatory cycle.

Evone® is an innovative mechanical medical ventilator, based on Flow-Controlled Ventilation of both inspiratory and expiratory flow.

FCV® creates a stable gas flow into or out of the patient's lungs to generate an inspiration or expiration, respectively.

FCV: Full respiratory control



<http://bit.ly/FCV-concept>

FCV® has an entirely dynamic flow profile, without pauses, aiming for linear changes in both volume and pressure. There are no abrupt intrathoracic pressure drops because of the controlled expiration.

- ▶ continuous
- ▶ linear
- ▶ identical inspiration: expiration (I:E) flow

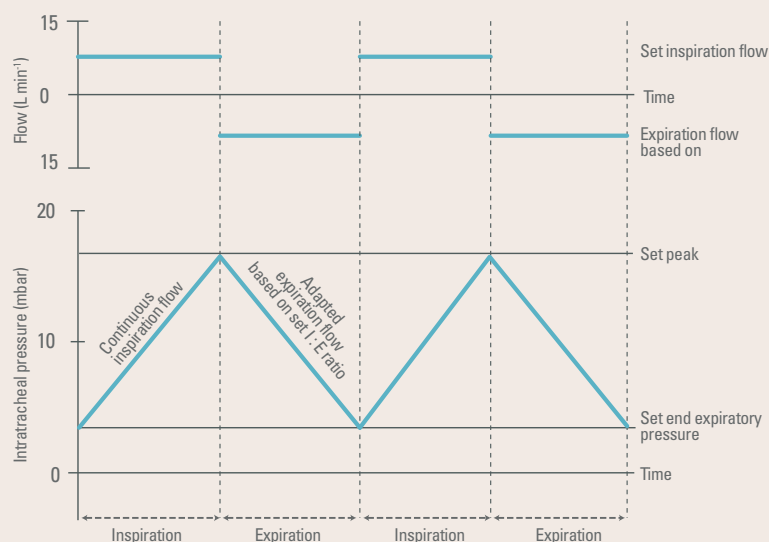
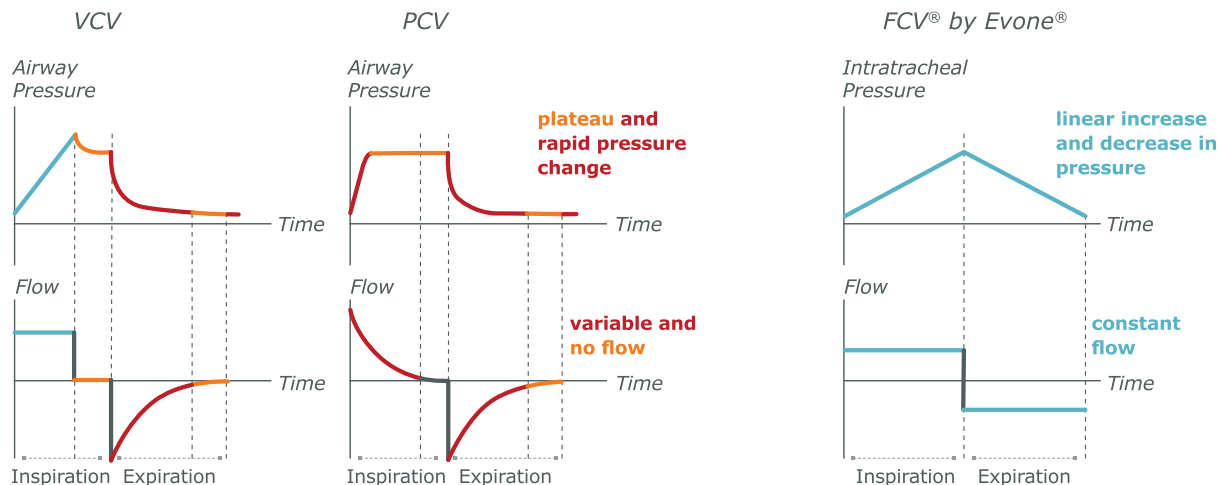


FIGURE. Setting flow-controlled ventilation requires four parameters: 1) end-expiratory pressure, 2) peak, 3) inspiration flow and 4) I : E ratio. At the set flow rate gas is insufflated from end-expiratory pressure (EEP) until it reaches peak level. Then the flow is reversed and sucked out at the rate to reach the set I : E ratio until EEP is reached. The next insufflation follows (Copyright: Ventivova Medical B.V.)

Inspiration is performed with the set (constant) Inspiration Flow until the intratracheal pressure reaches the set Peak pressure.

Evone® then starts an actively supported **expiration** phase resulting in controlled decline in intratracheal pressure until EEP with the set I:E is reached.

Evone® provides a meticulous **dynamic measurement** performed during both inspiratory and expiratory flow

Such reliable lung-mechanical data even permits a unique way of **individualized ventilation**

Inspiration Flow and **I:E ratio**, affect **Minute Volume** and **Frequency**:

Higher Flow → Higher Minute Volume and Higher Frequency
Longer Expiration → Lower Minute Volume and Lower Frequency

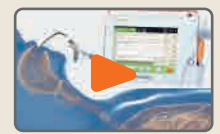
Peak Pressure and **EEP** determine the **Inspiratory Tidal Volume** and **Frequency**.

Higher Peak Pressure → Higher Inspiratory Tidal Volume and lower Frequency
Lower EEP → Higher Inspiratory Tidal Volume and lower Frequency

Note: Minute volume, tidal volume and respiratory rate are the result of adjustments to inspiratory flow, I:E ratio, PEAK pressure and EEP.



Evone® video



<http://bit.ly/4fg2V28>

Evone® enables Fully-Controlled Ventilation of a patient using various endotracheal tubes (~2 mm ID to ~10 mm ID).

Tritube® *

The ultrathin endotracheal tube, (2.4 mm Internal Diameter, 4.4 mm Outer Diameter) with an inflatable cuff to secure the airway.

Developed by Ventinova for small lumen FCV® ventilation mode.

- ▶ Difficult airway
- ▶ Head (Maxillofacial) and Neck (ENT) Anaesthesia
- ▶ Tracheal surgery
- ▶ Tracheostomy

Evone® is intended to be used in operating rooms and ICU environments in hospitals. All patients >40 Kg. IBW

*The benefits of **FCV®** relating to ventilation efficiency or low energy is not influenced by the use of the CTA with a conventional endotracheal tube or Tritube.

* **FCV®** ventilation can only be applied when the cuff of the endotracheal tube is fully inflated, sealing off the trachea from the ambient atmosphere and with total intravenous anesthetized (TIVA) patients.

Conventional Tube Adapter (CTA)*

CTA enables **FCV®** in the operating room and intensive care unit with an easy connection to any conventional endotracheal tube (size 5-10 mm ID).



- ▶ Connection to conventional single lumen tubes:
 - Improves ventilation efficiency in any surgery compared with conventional ventilation modes.
 - FCV results in smooth tidal movements of the diaphragm and thoracic wall
 - Coronary Artery bypass
 - Lung or oesophageal surgery
 - Laparoscopic or robotic abdominal surgery
 - Radiofrequency procedures (cardiac, liver or pancreatic)
 (Optionally use inspiration hold to maintain PEAK pressure or ventilation pause to maintain EEP pressure)
- ▶ Connection to Double lumen tubes to allow one and two lung ventilation
- ▶ Connection to (laser resistant) MLT-5 and MLT-6 during laryngeal surgery.

Small Lumen

"Tritube makes my life so much easier, as it provides a great view and an effective ventilation in the compromised airway"

Prof. Dr. Hans Mahieu

Laryngologist, Meander Hospital Amersfoort, The Netherlands

Surgical and lung mechanical benefits of Tritube and FCV during laryngeal surgery

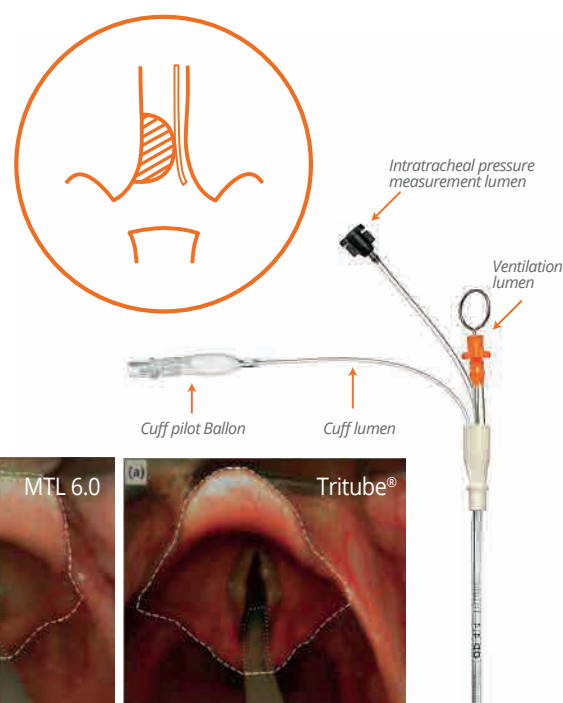
In the first randomized controlled trial Dr. Schmidt and colleagues showed clear clinical benefit of using Tritube and **FCV** over using a microlaryngeal tube (MLT-6) and Volume-Controlled Ventilation (VCV) in patients undergoing laryngeal surgery.²⁶

Tritube significantly reduced the concealment of laryngeal structures and thereby improved surgical conditions for surgeons with a lower level of expertise. Furthermore, the authors demonstrated that **FCV** enhanced lung aeration and improved the respiratory system compliance, while using similar PEEP and a lower inspiratory plateau pressure.²⁶

- ✓ **Tritube**® improves surgical conditions for surgeons.^{25,26,28,91,93}
- ✓ **FCV**® enhances alveolar recruitment and improves lung aeration compared to conventional ventilation modes.^{1-6,10,13,18,26}

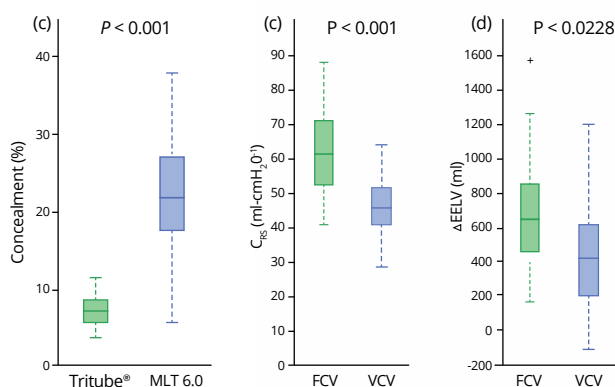
Ultrathin Tritube allowed safe intubation and ventilation in extremely narrow airway

In a patient with extreme airway obstruction due to a huge thyroid enlargement, Evone and Tritube prevented the use of ECMO to allow required surgery, as reported by Dr. Nabil Shallik (Hamad Medical Corporation, Qatar). Preoperative examination of the patient revealed a severe tracheal stenosis with a residual airway opening of only 4 mm, excluding the use of conventional endotracheal tubes to apply controlled ventilation. Instead, Tritube could be passed through the stenosis and allowed adequate ventilation using Evone during the six hour surgery³⁵



Glottic visibility for laryngeal surgery: Tritube vs. microlaryngeal tube

Adapted from Schmidt et al. EJA 2019



Shallik et al. Qatar Med J. January 2021 | Volume 2020 | Article 48³⁵

Potential Benefits Tritube®

The following benefits as compared to Volume Controlled Ventilation (VCV) and Pressure Controlled Ventilation (PCV) with conventional endotracheal tubes may be expected while ventilating patients in **FCV®** mode with ultrathin **Tritube®**:

- ✓ Provides an easier intubation especially in difficult airways ^{25, 28, 45, 91, 93}
- ✓ Provides unprecedented view of the intubated airway during oral, pharyngeal, laryngeal or tracheal procedures in adults ⁴⁵
- ✓ Provides improved surgical exposure as compared to an MLT-6 ^{26, 28}
- ✓ Clear sight and non-vibrating vocal cord ^{26, 28, 45, 46, 91, 93}
- ✓ Offers several new surgical options for treatment during ENT/laryngeal/tracheal surgery ^{27, 30, 31, 33-37, 45, 46, 91, 92, 93}
- ✓ Allows awake tracheal placement ^{36, 45}
- ✓ Allows adequate ventilation of adults in combination with Ventrain® or Evone® ^{25-30, 33-38, 45-55, 91-93}
- ✓ Is well tolerated in awake patients (>1 hour after surgery!) at least as well tolerated as an airway exchange catheter ^{27, 28, 45}
- ✓ Allows talking of intubated patients ^{27, 28, 45}
- ✓ Allows mask ventilation of intubated patients
- ✓ Reduces the risk on aerosol generation as compared to ventilation in an open airway ^{38, 91}

Jet Mode

Additionally, Evone has a (High Frequency) **Jet Ventilation mode**, which requires an open airway.

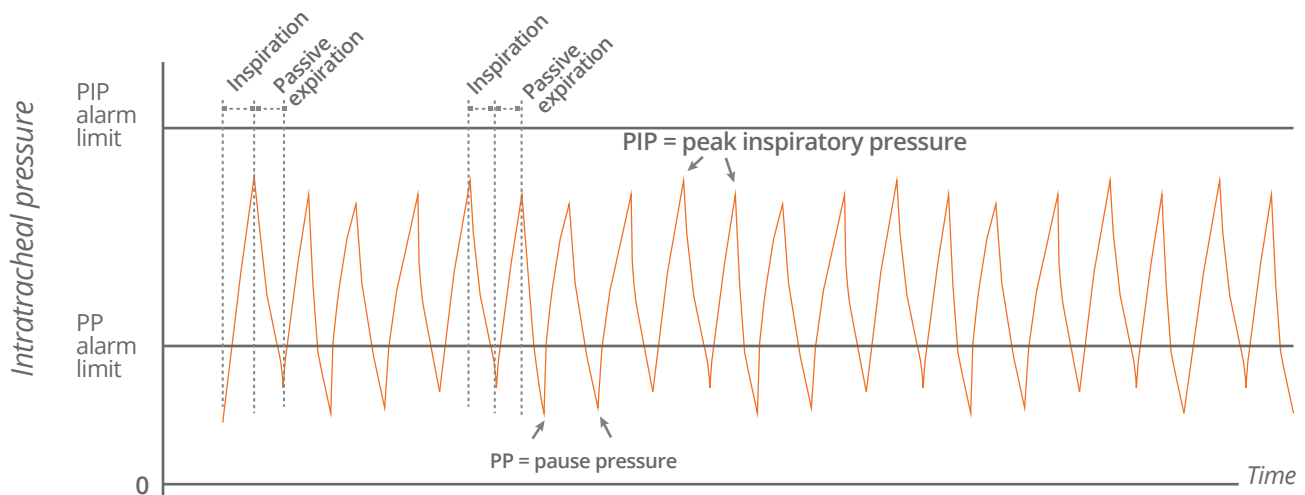
The Jet cycle is governed by three operator settings being:

- Frequency
- Inspiration Percentage
- Driving Pressure

The maximum driving pressure is limited to 1.5 Bar.

- ▶ Jet Mode, can be postoperatively used to liberate the patient from **FCV®** mechanical ventilation with **Tritube®** to stimulate spontaneous breathing. The cuff of **Tritube®** should be fully deflated to enable expiratory gases to freely egress.
- ▶ Double lumen laser Jet catheter.

Jet Mode intratracheal pressure : typical sequence of Jet breathing cycles is shown.

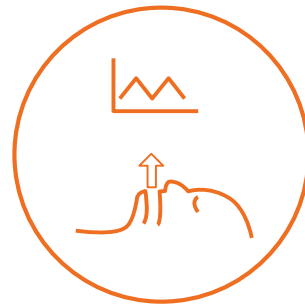


Higher Efficiency

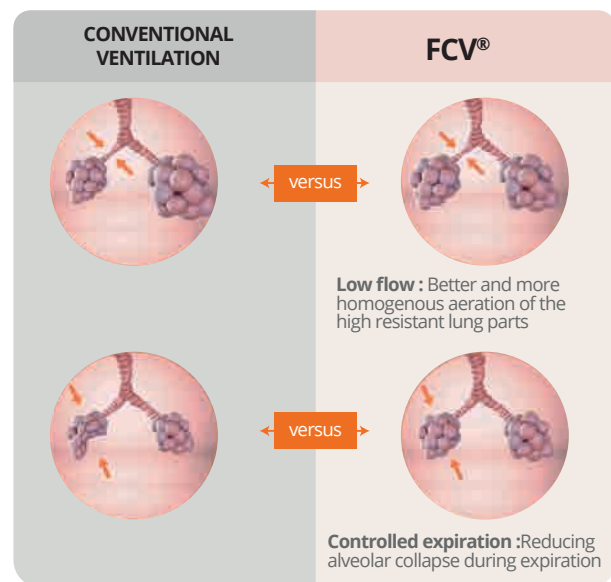
"FCV® keeps the lung open in a very smooth way"

Prof. Dr. med. Dietmar Enk

Inventor / Anesthesiologist / Intensivist, University Münster, Germany



- ▶ **FCV®** uses relatively low flow rates that range typically between 8 and 16 L/min to adequately ventilate a patient.
- ▶ At these lower flows, gas is better able to reach the lung units that have higher resistance and the dependent lung parts, that have a better perfusion.
- ▶ By controlling the expiration flow, **FCV®** maintains airway pressure and keeps the gas longer in the alveoli.
1, 3, 4, 10
- ▶ Thus, **FCV®** can avoid or delay airway and alveolar collapse, and thereby avoid atelectasis while improving gas exchange.
3, 4, 10, 13, 18, 26
- ▶ Together, **FCV®** results in a higher efficient ventilation as compared to conventional ventilation techniques.
1-6, 10, 13, 15, 16, 18, 26



CLINICAL EVIDENCE

Improved regional ventilation in obese patients by FCV® ¹⁹

The first clinical study comparing ventilation of obese patients with **FCV®** vs VCV was published in BMC Anesthesiology by Weber et al. With comparable tidal volumes and lower peak pressures, **FCV®** better maintained end-expiratory lung volume as compared to VCV ($P < 0.001$) during only seven minutes of ventilation, respectively. This strongly indicates that the constant expiratory flow during **FCV®**, in combination with an elevated mean intratracheal pressure, **has a recruiting effect and may help to prevent atelectasis often occurring during ventilation of obese patients.**

Improved one-lung ventilation with individually optimized FCV® ¹⁵

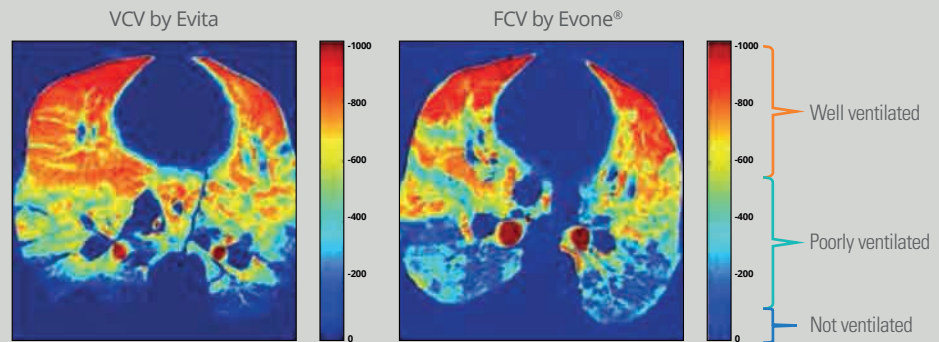
Dr. Abram and colleagues present the first randomized controlled trial to investigate the effect of individually optimized **FCV®** compared to best clinical practice PCV on gas exchange during one-lung ventilation (OLV). In total 46 patients were randomized to receive **FCV®** or PCV for the duration of general anesthesia. After 30 minutes of OLV, the Horowitz index was 37% higher in the **FCV®** group ($P = 0.047$), while a significantly lower minute volume was needed to obtain similar PaCO_2 levels. Thus, **FCV®** was found to be superior to PCV during OLV in terms of oxygenation and CO_2 removal, indicating a higher ventilation efficiency.

Adequate flow-controlled ventilation of patients with various lung conditions ⁹³

This publication by Dr. Grassetto and colleagues focuses on Tritube and Evone for laryngotracheal surgery, combining a retrospective observational study with an exhaustive narrative review of the existing literature. A series of 21 patients with various lung conditions undergoing different laryngotracheal surgery procedures was evaluated, including five patients with obesity, four with COPD, and one patient with a history of Covid-19. While Tritube was easily intubated and resulted in overall excellent surgical conditions, individually optimized flow-controlled ventilation facilitated adequate ventilation in all patients using relatively low minute volumes and global alveolar driving pressures. The authors conclude that this approach **'may represent an ideal approach that benefits surgeons, anesthesiologists, and patients with difficult airways and compromised lung mechanics.'**

Dynamic CT scans after 180 min **FCV**[®] and VCV

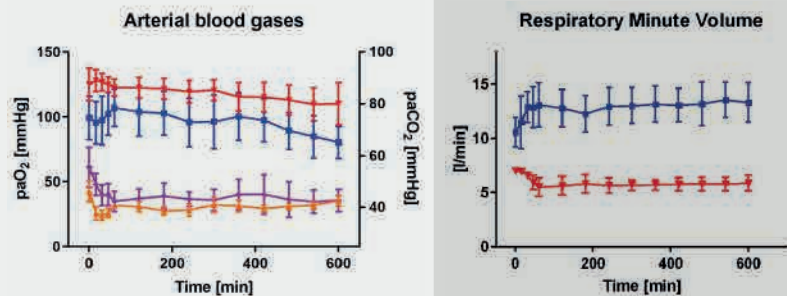
FCV[®] allowed significantly higher efficient ventilation in lung-sick pigs



Adapted from Schmidt et al., Crit Care Med 2020¹⁰

10 hours ventilation healthy pigs

- ✓ **FCV**[®] allowed higher efficient ventilation with significantly improved gas exchange.
- ✓ **FCV**[®] improved lung recruitment and maintained better lung aeration.
- ✓ **Evone**[®] allows individual optimization of ventilation settings based on compliance.



Adapted from Spraidier et al, Crit Care 2020³

FCV paO_2 FCV $paCO_2$ PCV paO_2 PCV $paCO_2$

Potential Benefits

The following benefits as compared to Volume Controlled Ventilation (VCV) and Pressure Controlled Ventilation (PCV) may be expected while ventilating patients in **FCV**[®] mode:

- ✓ Keeps the lung open by controlling the full ventilation cycle
- ✓ Results in better lung recruitment as compared to VCV and PCV^{3, 4, 10, 13, 18, 26}
- ✓ Results in better aeration of the lungs as compared to VCV and PCV^{3, 4, 10, 13, 18, 19, 26,}
- ✓ Provides higher efficient ventilation as compared to VCV, and PCV, evidenced by improved oxygenation and CO₂ removal^{1-6, 10, 13, 15, 16, 18, 26}
- ✓ Reduces atelectasis in dependent lung parts as compared to VCV in porcine ARDS and morbidly obese patients^{10, 19}
- ✓ **Evone**[®] allows individual optimization of ventilation settings based on compliance^{3, 7, 8, 13, 14, 17}



Lower Power

“Dissipated energy is minimized when FCV® is used”

Prof. emer. Tom Barnes

Fellow of the Institute of Physics, London, UK



Conventional mechanical ventilation generates more power than is needed to induce inspiration and expiration. The net overspill of energy is dissipated in the lungs, which has been shown even when applied for only a few hours to be a source of lung injury, so-called ‘ventilator-induced lung injury’ (VILI).

As energy dissipation can be calculated based on factors such as pressures, flow and respiratory rate, independent top leaders in the field postulated that the ideal ventilator should monitor and display energy dissipation in order to really apply ‘safe’ ventilation.

Over the last decades, innovative ‘lung-protective ventilation’ approaches have been developed to reduce VILI in the context of the two current golden standard ventilation techniques Pressure Controlled Ventilation (PCV) and Volume Controlled Ventilation (VCV).

Up to now, these strategies are limited to suggested values for tidal volume settings (6 mL/kg of predicted body weight), positive end expiratory pressure (PEEP) and plateau pressure in a “one size fits all” fashion.

While current ‘protective’ ventilation strategies mainly focus on optimizing inspiratory ventilation, the passive and abrupt expiration that occurs with conventional methods is considerably relevant and potentially a key factor in inducing lung damage.

FCV® results in lower energy dissipation

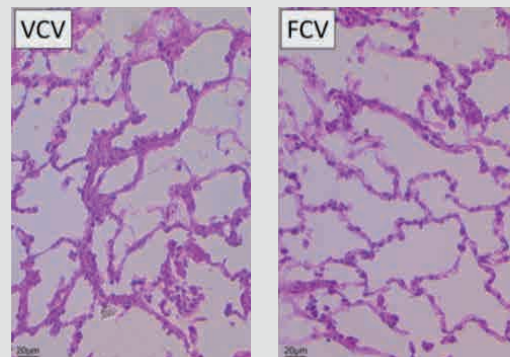
FCV® is based on the generation of a constant flow into and out of the lungs, resulting in linear increases and decreases of intratracheal pressures that are just high or low enough to facilitate mechanical breathing with efficient gas exchange.

The sudden alveolar pressure drop during passive expiration with conventional ventilation is prevented. In other words, the amount of energy generated by the ventilator is just enough to facilitate respiration.

Thereby, the impact on the lung tissue by dissipated energy is kept to a minimum, enabling ventilation with a markedly reduced risk of lung damage.^{23, 24}

Conventional mechanical ventilation: A cause of lung damage Ventilator-Induced Lung Injury (VILI)

- ✗ Mechanical ventilation applies energy to the respiratory system
- ✗ Excess energy is dissipated into the lungs and is a key factor for VILI
- ✗ Passive expiration is a source of dissipated energy
- ✗ Occurs frequently, even when ventilation is applied only for a few hours
- ✗ Is associated with high mortality rates on intensive care units (ICUs)
- ✗ Ideal ventilator should display energy dissipation, allowing ‘safe’ ventilation to be applied



Stained lung tissue samples retrieved after VCV or FCV® ventilation of ARDS pigs, revealing less thickening of alveolar walls in FCV® group, cell infiltration was lower, and surfactant protein A concentration was higher in the FCV® group, indicating the potential for FCV® to attenuate lung injury and to provide lung-protective effects.

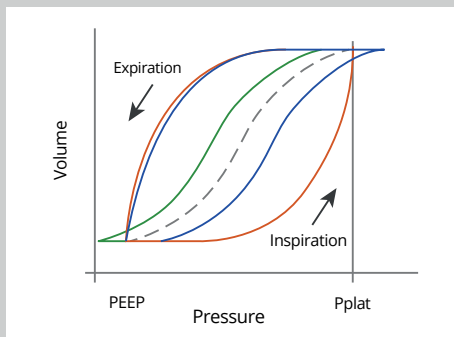
Adapted from Schmidt et al. 2020¹⁰

Recently, clear theoretical evidence was provided for lower energy dissipation in the lungs by **FCV**[®] as compared to VCV or PCV. A relatively simple analysis and numerical calculations indicated that energy dissipation is minimized by controlling the ventilation flow to be constant and continuous during both inspiration and expiration, and by ventilating at an I:E ratio close to 1:1. In other words, by using **FCV**[®] ²³

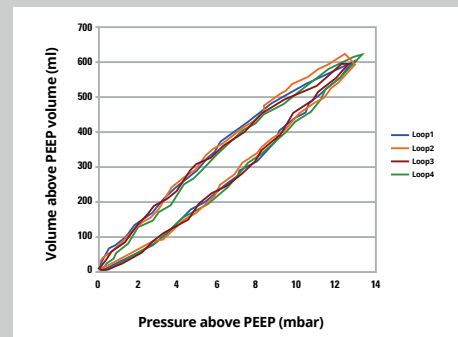
Energy dissipation can be calculated from the hysteresis area of pressure-volume loops obtained during ventilation. PV loops calculated based on routine ventilation protocols showed a 53% reduction in energy dissipation by **FCV**[®] as compared to PCV and a 32% reduction as compared to VCV. ²³

Additionally, it was emphasized that accurate measurement of intratracheal pressures is crucial for calculating energy dissipation. Where other VCV and PCV ventilators rely on calculated airway pressures, Evone is the only device that actually measures intratracheal pressures and is thus capable of measuring energy dissipation accurately.

This theory was further validated on a patient. Pressure-volume (PV) loops were recorded in real time, and the energy dissipated in the patient's lungs was calculated from the hysteresis area of the PV loops. Strikingly, the energy dissipation was just 0.17 J/L, which is even lower than values reported for spontaneous breathing (0.2–0.7 J/L) ²⁴



Left: Idealized PV loops (the enclosed area of each loop is the dissipated energy) during PCV (red line), VCV (blue line) and **FCV**[®] (blue line during inspiration, green line during expiration). The dashed line is the static compliance curve of the lung/chest system in this example.



Right: Real-time measured PV loops of a patient ventilated with **FCV**[®], demonstrating minimized hysteresis area of the PV loops (=energy dissipation).

Adopted from Barnes and Enk, TACC 2019 ²⁴

Potential Benefits

The following benefits as compared to Volume Controlled Ventilation (VCV) and Pressure Controlled Ventilation (PCV) may be expected while ventilating patients in **FCV**[®] mode:

- ✓ **FCV**[®] results in smooth tidal movements of the diaphragm and thoracic wall throughout the ventilation cycle.
- ✓ **FCV**[®] controls expiration and prevents abrupt airway pressure drop.

- ✓ Relies on accurately measured intratracheal pressures and inspiratory flows, allowing precise calculation of energy dissipation ^{23, 24}
- ✓ Hysteresis area of pressure-volume loops reflects the energy dissipated ²³
- ✓ Constant gas flow in combination with an I:E ratio of 1:1 minimizes energy dissipation down to values reported for spontaneous breathing ²³
- ✓ Provides ventilation with reduced mechanical power compared to VCV and PCV. ^{5, 10, 16, 23, 24}
- ✓ Has lung-protective potential ^{1, 4, 5, 8, 10, 14, 16, 18, 20, 22-24}

BIBLIOGRAPHY

1. FCV by Evone® – Ventilation effects

1.1 Lung-healthy subjects

1.1.1. Clinical studies

1) Weber J, Schmidt J, Straka L, Wirth S, Schumann S. Flow-controlled ventilation improves gas exchange in lung-healthy patients – a randomised interventional cross-over study. *Acta Anaesthesiol Scand*. 2019;00:1–8

2) Sebrechts T, Morrison SG, Schepens T, Saldien V. Flow-controlled ventilation with the Evone ventilator and Tritube versus volume-controlled ventilation. *Eur J Anaesthesiol*. 2021 Feb 1;38(2):209–211. doi: 10.1097/EJA.0000000000001326

1.1.2. Preclinical studies

3) Spraidier P, Martini J, Abram J, Putzer G, Glodny B, Hell T, Barnes T, Enk D. Individualized flow-controlled ventilation compared to best clinical practice pressure controlled ventilation: a prospective randomized porcine study. *Crit Care*. 2020 Nov 25;24(1):662. doi: 10.1186/s13054-020-03325-3

4) Schmidt J, Wenzel C, Mahn M, Spassov S, Schmitz HC, Borgmann S, Lin Z, Haberstroh J, Meckel S, Eiden S, Wirth S, Buerkle H, Schumann S. Improved lung recruitment and oxygenation during mandatory ventilation with a new expiratory ventilation assistance device: A controlled interventional trial in healthy pigs. *Eur J Anaesthesiol*. 2018 Oct;35(10):736–744

1.2 ARDS

1.2.1 Clinical data

5) Grassetto A, Pettenuzzo T, Badii F, Carlon R, Sella N, Navalesi P. Flow-controlled ventilation may reduce mechanical power and increase ventilatory efficiency in severe coronavirus disease-19 acute respiratory distress syndrome. *Pulmonology*. 2022 Jun 10;S2531-0437(22)00126-X.

6) Van Dessel E, De Meyer GR, Morrison S, Jorens PG, Schepens T. Ventilatory efficiency is improved during flow-controlled ventilation in ARDS. *Intensive Care Med Exp*. 2020;9(1):001167

7) Bergold M, Otterburg T, Woitzik J, Byhahn C. Flow-controlled ventilation – a novel approach to treating severe acute respiratory distress syndrome. Abstract presented at WAMM 2019

8) Spraidier P, Putzer G, Breitkopf R, Abram J, Mathis S, Glodny B, Martini J. A case report of individualized ventilation in a COVID-19 patient – new possibilities and caveats to consider with flow-controlled ventilation. *BMC Anesthesiol*. 2021. 21, 145. <https://doi.org/10.1186/s12871-021-01365-y>

9) Piowarczyk P, Bialka S, Pituch-Sala K, Borys M, Palaczynski P, Czuczwar M. Flow-controlled ventilation as a novel useful strategy in weaning from extracorporeal membrane oxygenation therapy in critical course of COVID-19 in parturient – case presentation. Poster 09AP02-06, presented at ESAIC 2022

1.2.2. Preclinical data

10) Schmidt J, Wenzel C, Spassov S, Borgmann S, Lin Z, Wollborn J, Weber J, Haberstroh J, Meckel S, Eiden S, Wirth S, Schumann S. Flow-Controlled Ventilation Attenuates Lung Injury in a Porcine Model of Acute Respiratory Distress Syndrome: A Preclinical Randomized Controlled Study. *Crit Care Med*. 2020; 48:e241–e248

11) Commented by: Enk D, Spraidier P, Abram J, Barnes T. Pressure Measurements in Flow-Controlled Ventilation. *Crit Care Med*. 2020 Dec;48(12):e1360–e1360. doi: 10.1097/CCM.0000000000000451. PMID: 33255124.

12) Response by: J. Schmidt, S. Schumann. The authors reply. *Crit Care Med*. 2020 Dec;48(12):e1360–e1361. doi: 10.1097/CCM.0000000000004653. PMID: 33255125.

1.3 Cardiac surgery

1.3.1. Clinical data

13) Wichelhaus LM, Kurz CT, Poepping J, Timmesfeld N, Zahn PK, Becker S. Flow-controlled versus pressure-controlled ventilation in on-pump cardiac surgery procedures: An explorative study on perioperative lung aeration based on Electrical Impedance Tomography data. Poster 07AP01-02, presented at ESAIC 2022

14) Spraidier P, Abram J, Putzer G, Wagner J, Hell T, Martini J. Gender differences in applied tidal volume with compliance titrated flow-controlled ventilation during cardiac surgery: – a subgroup analysis of a randomized controlled trial. Poster 07AP01-11, presented at ESAIC 2022

1.4 One-lung ventilation

1.4.1 Clinical data

15) Abram J, Spraidier P, Putzer G, Dejacó H, Velik-Salchner C, Martini J. Flow-controlled ventilation in thoracic surgery requiring one-lung ventilation – a randomized, controlled, single-center trial. Poster 07AP05-03, presented at ESAIC 2022

1.4.2 Preclinical data

16) Wittenstein J, Scharffenberg M, Ran X, Keller D, Michler P, Tauer S, Theilen R, Kiss T, Bluth T, Koch T, Gama de Abreu M, Huhle R. Comparative effects of flow vs. volume-controlled one-lung ventilation on gas exchange and respiratory system mechanics in pigs. *Intensive Care Med Exp*. 2020 Dec 18;8(Suppl 1):24. doi: 10.1186/s40635-020-00308-0.

17) Commented by Enk D, Abram J, Spraidier P, Barnes T. Dynamic compliance in flow-controlled ventilation. *Intensive Care Med Exp*. 2021 May 31;9(1):26. doi: 10.1186/s40635-021-00392-w. PMID: 34056674; PMCID: PMC8164913

18) Diaper J, Schranc A, Habre W, Albu G. Flow-controlled ventilation improved gas exchange during one-lung ventilation: a randomized experimental cross over study. Poster 07AP05-08, presented at ESAIC 2022

95) Spraidier P, Martini J, Abram J, Putzer G, Ranalter M, Mathis S, et al. Individualised flow-controlled ventilation versus pressure-controlled ventilation in a porcine model of thoracic surgery requiring one-lung ventilation: A laboratory study. *Eur J Anaesthesiol*. 2022 Nov 1;39(11):885–94.

1.5 Obese patients

1.5.1. Clinical data

19) Weber J, Straka L, Borgmann S, Schmidt J, Wirth S, Schumann S. Flow-controlled ventilation (FCV) improves regional ventilation in obese patients – a randomized controlled crossover trial. *BMC Anesthesiol*. 2020;20(1):24

1.6 Ex-vivo lung perfusion

1.6.1. Preclinical data

20) Ordies S, Orlitova M, Heigl T, Sacreas A, Van Herck A, Kaes J, Saez B, Vanstapel A, Ceulemans L, Vanaudenaerde BM, Vos R, Verschakelen J, Verleden GM, Verleden SE, Van Raemdonck DE, Neyrinck AP. Flow-controlled ventilation during EVLP improves oxygenation and preserves alveolar recruitment. *Intensive Care Med Exp*. 2020 Nov 25;8(1):70. doi: 10.1186/s40635-020-00360-w

1.7. Review articles and letters

1.7.1. History and application of FCV®

21) Bialka S, Palaczynski P, Szuldrzynski K, et al. Flow-controlled ventilation – a new and promising method of ventilation presented with a review of the literature. *Anaesthesiology Intensive Therapy*. 2022;54(1):62–70. doi: 10.5114/ait.2022.112889

1.7.2 Lung-protective potential of FCV®

22) Silva PL, Rocco PRM, Pelosi P. Personalized Mechanical Ventilation Settings: Slower Is Better! Vincent, JL (eds) Annual Update in Intensive Care and Emergency Medicine 2022. Springer, Cham. https://doi.org/10.1007/978-3-030-93433-0_9

23) Barnes T, van Asseldonk D, Enk D. Minimisation of dissipated energy in the airways during mechanical ventilation by using constant inspiratory and expiratory flows - Full-Controll ventilation. *Medical Hypotheses* 121 (2018); 167-176

24) Barnes T, Enk D. Ventilation for low dissipated energy achieved using flow control during both inspiration and expiration. *Trends in Anaesthesia and Critical Care* 2019(24); 5-12

2. FCV by Evone® – Small lumen ventilation (Tritube®)

2.1 Upper airway surgery

2.1.1. Clinical studies

25) Meulemans J, Jans A, Vermeulen K, Vandommele J, Delaere P, Vander Porten V. Evone® Flow-Controlled Ventilation During Upper Airway Surgery: A Clinical Feasibility Study and Safety Assessment. *Front. Surg*. 2020; 7:6. doi: 10.3389/fsurg.2020.00006

26) Schmidt J, Günther F, Weber J, Kehm V, Pfeiffer J, Becker C, Wenzel C, Borgmann S, Wirth S, Schumann S. Glottic visibility for laryngeal surgery: Tritube® vs. microlaryngeal tube - a randomized controlled trial. *Eur J Anaesthesiol*. 2019 Dec;36(12):963-971

27) Schmidt J, Günther F, Weber J, Wirth S, Brandes I, Barnes T, Zarbock A, Schumann S, Enk D. Flow-controlled ventilation during ear, nose and throat surgery. A prospective observational study. *Eur J Anaesthesiol*. 2019 May;36(5):327-334

28) Kristensen MS, Abildstrøm HH. Endotracheal video-laryngoscope guided intubation with a 2.4 mm cuff ed tube and active expiration by a dedicated ventilator versus a standard tube/ventilator. A randomized single blinded study in patients with a predicted difficult airway. - A paradigm shift in airway management? Abstract #3755 presented at Euroanaesthesia 2019 - Manuscript in preparation

91) Filairo M, Mora F, Vallin A, Della Casa P, Arceri C, Gratarola A, et al. Evone® Flow controlled ventilation: a new device for laryngotracheal surgery. *Acta Otorhinolaryngol Ital*. 2022 Apr;42(2):189–93.

92) Kuut MH, Honings J, Marres HAM, Mourisse JMJ, Verhagen AFTM. Controlled mechanical ventilation through a narrow bore lumen during tracheal surgery: A prospective observational study. *Eur J Anaesthesiol*. 2022 Jul 26;

93) Grassetto A, Pettenuzzo T, Badii F, Barzaghi F, Carlon R, Dellarole S, et al. A new perspective during laryngo-tracheal surgery: the use of an ultra-thin endotracheal tube (Tritube®) and flow-controlled ventilation—a retrospective case series and a review of the literature. *Journal of Anesthesia, Analgesia and Critical Care*. 2022 Aug 26;2(1):39.

2.1.2. Clinical cases

29) Leow TYS, Van der Wal RAB, Marres HAM, Honings J. Intubation with a TriTube to avoid peri-operative tracheostomy in open airway surgery. *J Laryngol Otol*. 2022 Feb 23;1-16. doi: 10.1017/S002221512200024X. Epub ahead of print. PMID: 35193715.

30) Martinez Botet L, Siroki Borgonovo F, Mora Rivas E, Hinojal Olmedillo B. Tritube use in 12 year girl underwent scheduled laryngeal papilloma resection. Poster 11AP04-07, presented at ESAIC 2022

31) Mallam L, Massingberd-Mundy D, Girgis M, De Zoysa N. Near total intrathoracic airway obstruction managed with a Tritube® and flow-controlled ventilation. *Anaesth Rep*. 2022 Feb 28;10(1):10.1002/anr.3.12156. doi: 10.1002/anr.3.12156. PMID: 35252872; PMCID: PMC8885748

32) Böttiger L, Uriarte J, van der Hooft JWA. Near total intrathoracic airway obstruction managed with a Tritube (R) and flow-controlled ventilation: a reply. *Anaesth Rep*. 2022 Mar 22;10(1):e12155. doi: 10.1002/anr.3.12155. PMID: 35360362; PMCID: PMC8941302.

33) Bailey JR, Lee C, Nouraei R, Chapman J, Edmond M, Girgis M, De Zoysa N. Laryngectomy with a Tritube® and flow-controlled ventilation. *Anaesthesia Reports* 2021, 9: 86-89. <https://doi.org/10.1002/anr.3.12114>

34) Yilbas AA, Melek A, Canbay O, Kanbak M. Experience with Tritube and Flow-Controlled Ventilation During Airway Surgery. *Turk J Anaesthesiol Reanim*. 2021;49(3):269-270.

35) Shallik N, Elarref M, Khamash O, Abdelaal A, Radi Alkhafaji M, Makki H, Abusabeib A, Moustafa A, Menon A. Management of critical tracheal stenosis with a straw sized tube (Tritube®): Case report. *Qatar Med J*. 2021 Jan 28;2020(3):48. doi: 10.5339/qmj.2020.48. PMID: 33598418; PMCID: PMC7842837.

36) Jeyarajah K, Ahmad I. Awake tracheal placement of the Tritube under flexible bronchoscopic guidance. *Anaesthesia Cases / 2018-0097 / ISSN 2396-8397* epub Jul 2018

37) Piosik ZM, Todsén T, Balle JS, Abildstrøm H, Kristensen MS. Ultra-narrow 2.4 mm id Tritube® together with Evone® ventilation allows surgical access and controlled ventilation even in case of severe stenosis. *Trends in Anaesthesia and Critical Care* 2018 (23); 20

2.2. Tracheostomy

2.2.1 Clinical data

38) Magasich-Airola NP, Martins MR, Desuter GR, Van Boven MJ. Novel technique for safe tracheostomy during COVID-19 pandemic using Evone® flow-controlled ventilation system. *Int J Clin Pract*. 2020 Nov 27:e13863. doi: 10.1111/ijcp.13863. Online ahead of print.

2.3 Review articles

- 39) Nouraei SAR, Gargis M, Shorthouse J, El-Boghdady K, Ahmad I. A multidisciplinary approach for managing the infraglottic difficult airway in the setting of the Coronavirus pandemic. *Oper Tech Otolaryngol Head Neck Surg.* 2020 Jun;31(2):128-137. doi: 10.1016/j.otot.2020.04.009. Epub 2020 May 30. PMID: 32572325; PMCID: PMC7260599
- 40) Schleicher A, Groeben H. Anesthetic considerations for tracheobronchial surgery. *J Thorac Dis.* 2020 Oct;12(10):6138-6142. doi: 10.21037/jtd.2020.02.52

3. EVA by Ventrain®

3.1 Review articles

- 41) De Wolf M, Enk D, Jagannathan N. Ventilation through small-bore airways in children by implementing active expiration. *Paediatr Anaesth.* 2022 Feb;32(2):312-320. doi: 10.1111/pan.14379. Epub 2021 Dec 22. PMID: 34902197
- 42) Dos Santos Rocha A, Habre W, Albu G. Novel ventilation techniques in children. *Paediatr Anaesth.* 2022 Feb;32(2):286-294. doi: 10.1111/pan.14344. Epub 2021 Dec 5. PMID: 34837438
- 43) Morrison S, Aerts S, Saldien V. The Ventrain Device: A Future Role in Difficult Airway Algorithms? *A A Pract.* 2019;13:362-365
- 44) Doyle DJ. Ventilation via Narrow-Bore Catheters: Clinical and Technical Perspectives on the Ventrain Ventilation System. *The Open Anaesthesia Journal* 2018, Volume 12

3.2 Small lumen ventilation

3.2.1. Clinical data – Upper airway surgery

- 45) Kristensen MS, de Wolf MWP, Rasmussen LS. Ventilation via the 2.4 mm internal diameter Tritube® with cuff - new possibilities in airway management. *Acta Anaesthesiol. Scand.* 2017 Jul; 61(6):580-589
- 46) Rodríguez L, Sanchez Palomo JJ, Lopez Salcedo MA, Pizarro NE, Fossati Puertas S, Santé Serna L. Cutting-edge ventilation method in laryngeal microsurgery. Abstract #3280 presented at Euroanaesthesia 2019
- 47) Lee S, Yeow D, Molena E, Pitkin L, Patel B. The Ventrain - An elegant way to facilitate elective surgery in upper airway obstruction. *Trends in Anaesthesia and Critical Care* 2020 (30) e13
- 48) Zuercher M, Pythoud-brügger M, Sandu K, Schoettler P. Combined use of Ventrain and S-Guide for Airway Management of Severe Subglottic Stenosis. *Türk J Anaesthesiol Reanim* 2019 Jun;47(3):238-241
- 49) Onwochei DN, El-Boghdady K, I. Ahmad I. Two-Stage Technique Used to Manage Severe Upper Airway Obstruction and Avoid Surgical Tracheostomy: A Case Report. *A A Pract* 2018 Mar 1;10(5):118-120
- 50) Fearnley RA, Badiger S, Oakley R, Ahmad I. Elective use of the Ventrain for upper airway obstruction during high frequency jet ventilation. *J Clin Anesth.* 2016 Sep;33:233-5. doi: 10.1016/j.jclinane.2016.03.024. Epub 2016 May 5. PMID: 27555171.
- Borg PA, Hamaekers AEW, Lacko M, Jansen J, Enk D. Ventrain for ventilation of the lungs. *Br J Anaesth.* 2012 Nov;109(5):833-4
- 51) Monnier Y, Schoettler P, Morisod B, Ikonomidis C, Simon C. Transthyroid access to the larynx for endoscopic resection of early-stage glottic cancer. *Head Neck* 2016 Aug;38(8):1286-9
- 52) Kalkoff M. Ventilation through a small-bore intubating catheter using Ventrain in an elective procedure. *Letter Br J Anaesth* 2012
- 53) Braga BAJ, Rodeny G, Hotvedt G, Taylor AFH, Ball DR. Ventrain ejector ventilation as a bridge to tracheal intubation for complex NOMA pathology. Poster presented at the Difficult Airway Society 2014 and World Airway Management Meeting 2015

3.2.2. Preclinical data

- 54) De Wolf MWP, van der Beek T, Hamaekers AE, Theunissen M, Enk D. A prototype small-bore ventilation catheter with a cuff: cuff inflation optimizes ventilation with the Ventrain. *Acta Anaesth Scand* 2018 Mar 62(3):328-335
- 55) Paxian M, Preussler NP, Reinz T, Schlueter A, Gottschall R. Transtracheal ventilation with a novel ejector-based device (Ventrain) in open, partly obstructed, or totally closed upper airways in pigs. *Br J Anaesth* 2015 Aug;115(2):308-16.

3.3. Emergency

3.3.1 Clinical data

- 56) Morrison S, Aerts S, van Rompaey S, Vanderveken O. Failed Awake Intubation for Critical Airway Obstruction Rescued With the Ventrain Device and an Arndt Exchange Catheter: A Case Report. *A A Pract.* 2019 Jul 1;13(1):23-26
- 57) Heuveling DA, Mahieu HF, Jongsma-van Netten HG, Gerling V. Transtracheal Use of the CriCath Cannula in Combination With the Ventrain Device for Prevention of Hypoxic Arrest due to Severe Upper Airway Obstruction: A Case Report. *A A Pract.* 2018 Dec 5;11(12):344-347
- 58) Wahlen BM, Al-Thani H, El-Menyar A. Ventrain: from theory to practice. Bridging until re-tracheostomy. *BJM Case Rep* 2017 Aug 16; 2017
- 59) López-Torres J, Escrivá FJ, Encarnación J, Alonso J, Cuchillo JV, Argente P. Ventrain device for difficult or obstructed airways: 4 case report. *Trends in Anaesthesia and Critical Care* 2017 12:31
- 60) Krapf M, Gümmand M, Jacquier J, Graf S. Cannot intubate, cannot ventilate: Beatmung über einen 2-mm-Katheter in der Präklinik. *Notfallpraxis* 2016 8(39): 792-794 (article in German)
- 61) Nellgård P. Ventrain in a case of can't intubate can't ventilate situation. Orally presented at the European Society of Anaesthesiology 2013
- 62) Kalsi A, Konieczny K, Turner M. Transtracheal jet ventilation using the Ventrain Device in a patient with severe upper airway obstruction. Poster presented at the Difficult Airway Society 2012
- 63) Rosenblatt W, Popescu W. Master techniques in Upper and Lower Airway Management. *Wolters Kluwer Health* (publisher); 2015; Chapter 44 (ePub)

3.3.2 Preclinical data

- 64) Mann CM, Baker PA, Sainsbury DM, Taylor R. A comparison of cannula insufflation device performance for emergency front of neck airway. *Paediatr Anaesth.* 2021 Jan 11. doi: 10.1111/pan.14128. Epub ahead of print. PMID: 33432628
- 65) De Wolf MWP, Gottschall R, Preussler MP, Paxian M, Enk D. Emergency ventilation with the Ventrain through an airway exchange catheter in a porcine model of complete upper airway obstruction. *Can J Anaesth.* 2017 Jan;64(1):37-44

- 66) Hamaekers AEW, van der Beek T, Theunissen M, Enk D. Rescue ventilation through a small-bore transtracheal cannula in severe hypoxic pigs using expiratory ventilation assistance. *Anesth Analg.* 2015 Apr;120(4):890-4

- 67) Berry M, Tzeng Y, Marsland C. Percutaneous transtracheal ventilation in an obstructed airway model in post apnoeic sheep. *Br J Anaesth.* 2014 Dec;113(6):1039-45

- 68) Ziebart A, Garcia-Bardon A, Kamuf J, Thomas R, Liu T, Schad A, Duenges B, David M, Hartmann EK. Pulmonary effects of expiratory-assisted small-lumen ventilation during upper airway obstruction in pigs. *Anaesthesia.* 2015 Oct;70(10):1171-9

- 69) Manoach S, Paladino L, Rosenblatt W. Resuscitation from prolonged apnea and upper airway obstruction in a large ovine model: a pilot trial of transtracheal ventilation using 15 lpm with and without an entrainment assisted trans-catheter exhalation device. Poster presented at the Society for Airway Management 2011

3.4. Pediatric ventilation

3.4.1 Clinical data

- 70) Escrivá Alepuz FJ, Alonso García J, Cuchillo Sastriques JV, Alcalá E, Argente Navarro P. Emergency Ventilation of Infant Subglottic Stenosis Through Small Gauge Lumen Using the Ventrain®. *A A Pract* 2018 Mar 15;10(6):136-138

- 71) Willemsen MG, Noppens R, Mulder AL, Enk D. Ventilation with the Ventrain through a small lumen catheter in the failed paediatric airway: two case reports. *Br J Anaesth* 2014 May;112(5):946-7

3.5. One lung ventilation

3.5.1 Clinical data

- 72) Piccioni F, Caccioppola A, Rosboch GL, Templeton W, Valenza F. Use of the Ventrain Ventilation Device and an Airway Exchange Catheter to Manage Hypoxemia During Thoracic Surgery and One-Lung Ventilation. *J Cardiothorac Vasc Anesth.* 2021 Jun 25;S1053-0770(21)00529-2. doi: 10.1053/j.jvca.2021.06.023. Epub ahead of print. PMID: 34294514

- 73) Evers VM, Immink RV, van Boven WJP, van Berge Henegouwen MI, Hollmann MW, and Veelo DP. Intraoperative Use of the Ventrain for Single Lung Ventilation After Iatrogenic Trauma to the Left Main Bronchus During Thoracoscopy: A Case Report. *A A Case Rep* 2017 Aug 15; 9(4):116-118
- Commented by Grocott HP. Using the Ventrain With a Small-Bore Catheter: Ventilation or Just Oxygenation? *Anesth Analg.* 2018 Apr;126(4):1426-1427

3.6. Technology development

- 74) Hamaekers AEW, Borg PA, Enk D. Ventrain: an ejector ventilator for emergency use. *Br J Anaesth.* 2012 Jun;108(6):1017-21

- 75) Berlin DA, Manoach S, Oromendia C, Heerdt P. Automated expiratory ventilation assistance through a small endotracheal tube can improve venous return and cardiac output. *Intensive Care Med* 2019, 7(1), 22

- 76) Commented by Böttinger L and van der Hooft JWA. Negative pressure ventilation – a special application of expiratory ventilation assistance. *Intensive Care Med* 2019, 7(1), 22.
- Response by Berlin DA, Manoach S, Heerdt PM. Response to letter by Drs Böttinger and van der Hooft. *Intensive Care Med* 2019 Jun;7(1):31

- 77) Hamaekers AEW, Borg PA, Götz T, Enk D. The importance of flow and pressure release in emergency jet ventilation devices. *Paediatr Anaesth.* 2009 May;19(5):452-7

- 78) Hamaekers AEW, Borg PA, Enk D. A bench study of ventilation via two self-assembled jet devices and the Oxygen Flow Modulator in simulated upper airway obstruction. *Anaesthesia.* 2009 Dec;64(12):1353-8

- 79) Hamaekers AEW, Götz T, Borg PA, Enk D. Achieving an adequate minute volume through a 2 mm transtracheal catheter in simulated upper airway obstruction using a modified industrial ejector. *Br J Anaesth.* 2010 Mar;104(3):382-6

- 80) Hamaekers AEW, Borg PA, Götz T, Enk D. Ventilation through a small-bore catheter: optimizing expiratory ventilation assistance. *Br J Anaesth.* 2011 Mar;106(3):403-9

- 81) Calderon LGMB, Moreira MM, Emidio GL, Corrêa EP, Carvalho-Filho MA, Terzi RGG. Expiratory ventilation assistance (EVA®) through a 14G catheter (2mm) in a Totally Obstructed Airway (TOA). Poster presented at Society for Airway Management 2013

- 82) Schmidt AR, Ruetzler K, Haas T, Schmitz A, Weiss M. Impact of oxygen sources on performance of the Ventrain® ventilation device in an in vitro set-up. *Acta Anaesthesiol Scand.* 2016 Feb;60(2):241-9. Rebuttal by de Wolf MW, Schutze-Weissmann JM. *Acta Anaesthesiol Scand.* 2016 Nov;60(10):1477-1478

- 83) Wirth S, Seywert L, Spaeth J, Schumann S. Compensating Artificial Airway Resistance via Active Expiration Assistance. *Respir Care.* 2016 Dec;61(12):1597-1604

- 84) Schmidt AR, Ruetzler K, Haas T, Schmitz A, Weiss M. Monitoring der Tidalvolumina bei Verwendung des Ventrain® Notfallbeatmungsgerätes. *Anaesthesist* 65:514–520. Rebuttal by de Wolf, Gottschall and Enk. *Anaesthesist* 2017. 66:207–208

4.0 Handbooks

- 85) Cook T, Kristensen MS. Core Topics in Airway Management, 3rd ed. Cambridge University Press (publisher); 2020; Chapters 18, 20, 23

- 86) Hagberg C. Benumof & Hagberg's Airway Management, 4th ed. Elsevier (publisher); 2018; p.106-107; p. 865-866

- 87) Hagberg C. Benumof & Hagberg's Airway Management, 3rd ed. Elsevier (publisher); 2013; p.595-6.

- 88) Barash PG, Cullen BF, Stoelting RK, Cahalan M, Stock MC, Ortega R. Clinical Anesthesia, 7th ed. Wolters Kluwer Health (publisher); 2013; p.798

- 89) Spies C, Kastrup M, Kemer T, Melzer-Gartzke C, Zielke H, Kox WJ. SOPs in Anästhesiologie und Schmerztherapie. Thieme (publisher); 2013; p.94

- 90) Dornberger. Schwieriges Atemwegsmanagement bei Erwachsenen und Kindern. Thieme (publisher); 2013; p.251-2

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