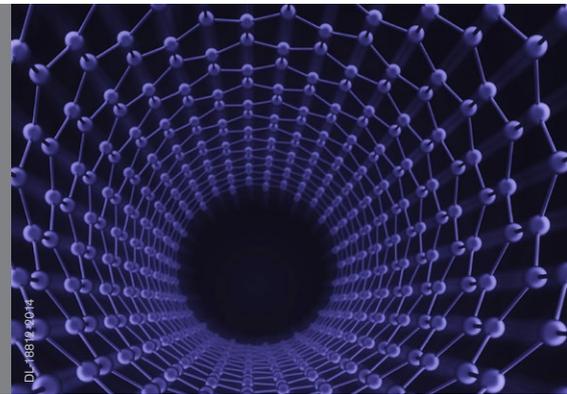


## Technology Insights

### for protective ventilation and spontaneous breathing in the OR

Protective ventilation in the OR poses major requirements to anaesthesia Workstations. Dräger works closely with clinicians and nursing staff around the world to understand the precise needs and requirements for protective ventilation in the OR.

Below we describe the latest ventilation technologies in our anaesthesia workstations enabling successful protective ventilation strategies.



Discussion of the benefits of protective breathing strategies in the OR and the way they should be realised has intensified markedly in recent years. Studies have shown that many patients benefit from protective ventilator settings during surgery and that the outcome can be improved - and not only for patients with an increased risk of pulmonary complications.

A wide range of parameters for mechanical ventilation have been investigated. Some of them have proven to be effective, while the evidence for others is not so clear. However, recommendations based on the latest data are available.

Background information to the following recommendations and the topics of perioperative spontaneous breathing and the complexity of anaesthesiological workstations is given in our clinical white paper ([click here](#)).

Current recommendations for protective ventilation in the OR:

1. Tidal volume: 6-8 ml per kg ideal body weight
2. PEEP: 2-5 mm H<sub>2</sub>O for normal-weight patients
3. Driving pressure: if possible <16 mm H<sub>2</sub>O
4. FiO<sub>2</sub>: low if possible, around 0.4
5. Recruitment: no standard recruitment

At present the discussion surrounding perioperative protective ventilation focuses on the parameters of mechanical ventilation. Yet two very interesting factors are given little attention. Firstly, intraoperative spontaneous

breathing can help alleviate the negative aspects of mechanical ventilation. Secondly, any concept can only exert its beneficial effects if it is implemented consistently.

This also applies to protective ventilation strategies. Anaesthetists' complex workstations and the large number of distractions that occur during a single case can adversely affect patient care and hinder the consistent application of such concepts. Here medical technology has to support protective mechanical ventilation by providing intelligent technical solutions, enable and promote spontaneous breathing, and reduce the complexity of the anaesthesiological workstation to the minimum.



Below we describe some technical solutions that enable and promote intraoperative protective ventilation.

## SUPPORTING TECHNOLOGY FOR PERIOPERATIVE PROTECTIVE VENTILATION, PROMOTION OF SPONTANEOUS BREATHING, AND REDUCTION OF THE COGNITIVE WORKLOAD

### Reliable and precise application of ventilation pressure and tidal volume

The electrically powered ventilators - especially the piston-driven ventilator E-Vent/E-Vent plus - which are installed in Dräger anaesthesia machines, enable extremely precise and safe tidal volume dosing. Even in the unlikely event of a complete defected flow measurement, controlled ventilation can still be performed.

In addition, all Dräger anaesthesia machines have compliance compensation. In this context, compliance means the ability of the ventilation hose to stretch and expand and take up part of the delivered volume when ventilation pressures are applied. Advanced ventilators are able to compensate for the compliance of the breathing system by delivering sufficient additional volume with each breath to ensure that the patient actually receives the volume set. Dräger anaesthesia machines determine the compliance of the breathing system and ventilation hoses during the self-test or the leak test.

Furthermore, the CO<sub>2</sub> absorber in all current Dräger anaesthesia machines is located in the low pressure part of the breathing systems between the bag and the ventilator. This reduces the compressible volume during inspiration, which improves system compliance and enables an optimal ventilation performance.

In order to ensure precise application of the ventilation pressures and the tidal volume, all current Dräger anaesthesia machines also feature fresh gas decoupling. Unlike fresh gas compensation, fresh gas decoupling ensures that fresh

gas setting changes or the oxygen delivered during O<sub>2</sub> flush will not influence the ventilation pressures and tidal volumes applied during mechanical ventilation. In the Fabius® and Primus® families, fresh gas decoupling is enabled via a valve between the fresh gas inlet and the ventilator. This valve ensures that during inspiration fresh gas is guided into the reservoir (bag) and in the next expiration is guided out of the bag and together with additional fresh gas into the cylinder.

The Zeus® family and the Perseus® A500 devices with the TurboVent 2 ventilator, do not need a fresh gas decoupling valve to apply precisely the ventilation pressures and tidal volumes, without being influenced by the fresh gas flow and oxygen during O<sub>2</sub> flush. In these products, ventilation is controlled by changing the rotation of the blower unit's impeller. The fresh gas flow changes are very fast applied, still during inspiration. A very fast control circuit adapts also the blower speed to enable the application of pressure and flow (which is decoupled from fresh gas) even without such a valve.

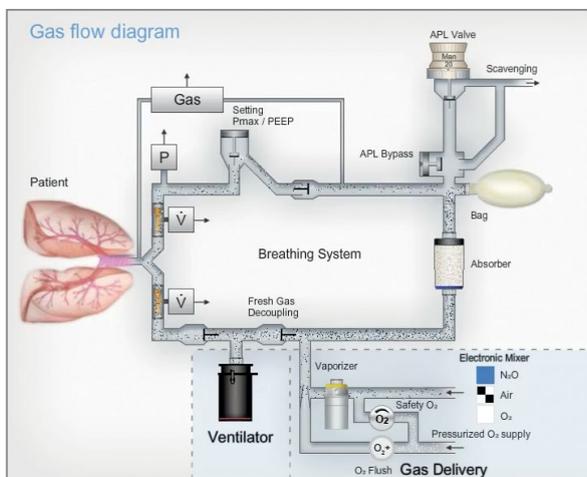
For more information about Dräger ventilator technology please click [here](#).

### Default settings for ventilation and fresh gas

The anaesthesia machines in the Primus®- and Zeus® families and the Perseus® A500 - can start ventilation with pre-set values for the ventilation parameters, such as tidal volume and breathing frequency based on ideal bodyweight, if the patient's height and ideal body weight are entered. The corresponding ventilation settings are calculated from these data. In standard configuration, these settings can be pre-defined according to department or hospital protocols. This is especially important and necessary in regards of protective ventilation strategies, since the recommendations for low tidal volumes per kg of body weight always refer to ideal body weight. It is also possible to pre-set the flow and concentration of fresh gas which the device delivers at the start of the operation. This can support the recommended FiO<sub>2</sub> dosage.

### Breathing system resistances

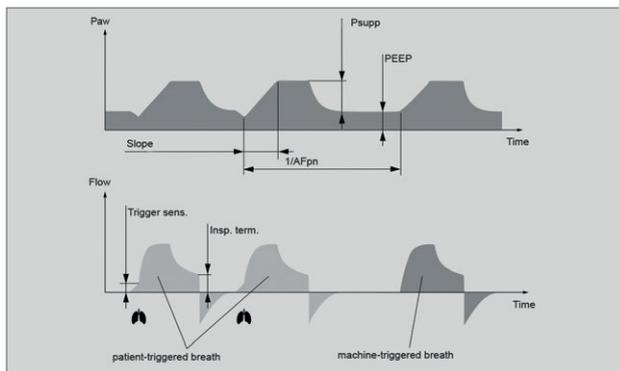
In the blower-driven anaesthesia machines in the Zeus® family and the Perseus® A500, the circular flow reduces the resistances of the breathing system, and this facilitates spontaneous breathing and reduces the work of breathing. With these systems, the patient can breathe spontaneously at any time, even during inspiratory phase and at the PEEP (CPAP) level. During expiration, the E-Vent and E-Vent plus piston-driven ventilators in the Fabius® and Primus® families synchronise the expiratory phase with the expiration flow, and actively support the patient's expiration by regulating the pistons' movement accordingly.



Gas Flow Diagram for Primus®

### Synchronisation and support for spontaneous breathing

The current anaesthesia machines offer the option of synchronising mechanical ventilation with the patient's spontaneous breathing. All Dräger anaesthesia machines offer controlled ventilation with pressure support and stand-alone pressure support modes which support the spontaneous breathing to achieve the targeted tidal volume and to reduce work of breathing. The very high trigger sensitivity, which can be adjusted to the individual patient, coupled with the fast reactions of the electronic ventilators E-Vent/E-Vent plus and especially TurboVent 2, ensure rapid and synchronous pressure support for spontaneous breathing. The slope setting can be used to adjust the speed of the applied pressure according to the individual lung mechanics. Synchronisation and reaction times of Dräger's modern ventilator technologies, especially the TurboVent 2 blower, correspond to the performance of intensive care ventilators.



Pressure Support

PEEP (CPAP) is maintained during the expiration phases. In systems with blower-driven ventilators, spontaneous breathing is possible at all times and in all ventilation modes, independent of the activation of synchronisation, and even during inspiratory phase and at PEEP (CPAP) level.

### Volume control – AutoFlow

Recent studies have shown that low tidal volumes are a key part of protective ventilation strategies. Tidal volumes can be harmful, especially for lungs with reduced compliance, because they can lead to high driving pressures. Along with this Tidal volume appears not to be the only protective or injury-causing factor. It is only in combination with lung compliance that pressures result which can be harmful. High pressures, therefore, have to be avoided, but at the same time tidal volumes must be applied that enable sufficient ventilation. Therefore, Dräger anaesthesia machines of the Primus®- and Zeus® families and the Perseus® A500 offer Volume Control AutoFlow ventilation mode, which combines the advantages of volume-controlled and pressure-controlled ventilation. Just as in the classical volume-controlled ventilation mode, the tidal volume can be set to the desired value.

However, as with pressure-controlled ventilation, this is applied with decelerating inspiratory flow. The anaesthesia machine ventilates the patient as in pressure-controlled mode, with the lowest possible inspiratory pressure, which is automatically selected, to deliver the set tidal volume. In particular in operations during which changes in lung compliance occur, e.g. during laparoscopic interventions, this form of ventilation guarantees to apply the desired tidal volume with the lowest possible minimum inspiratory pressures and driving pressures. When using the AutoFlow volume-control mode, it is important to set a limit for the inspiratory pressure via the "Pmax" setting.

### Airway Pressure Release Ventilation (APRV)

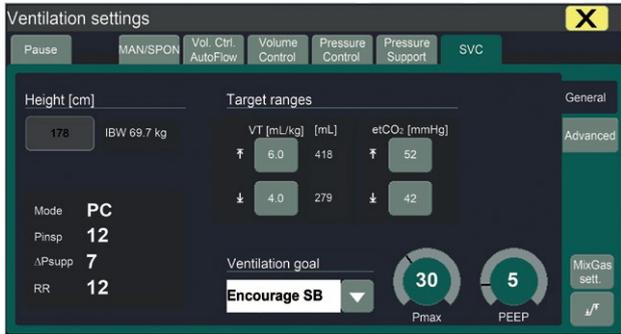
In the light of the discussion on the significance and design of protective ventilation strategies in the OR, it appears expedient that in particular patients who enter the OR from the intensive care unit should - wherever possible - continue to receive the ventilation therapy that was already being applied in the ICU. Especially for critical patients ventilated in the ICU using APRV it appears to be desirable, or even necessary, to continue with this ventilation mode in the OR. The blower technology in the Perseus® A500 is ideally suited to maintaining the long  $P_{high}$  phases when the patient can breathe spontaneously, and to ensuring short, precise release phases. This is not the only way that Dräger brings ICU-quality ventilation to the OR.

### Smart Ventilation Control (SVC)\*

SVC is the first assistance system for ventilation in the OR which supports users during the entire operation, from intubation all the way to extubation.

In contrast to conventional ventilation modes, users can indicate directly the therapeutic objective of ventilation. In this context, the objective of ventilation refers to the definition provided by the anaesthetist concerning whether the patient should have fully controlled ventilation, or whether spontaneous breathing should be permitted or forced. At the start, the system suggests target ranges for tidal volume and end tidal  $CO_2$  adapted to each individual patient. The users have the option to adjust these target ranges. SVC automatically adapts the relevant ventilation parameters continuously to keep tidal volume and end tidal  $CO_2$  always within the target ranges. This ensures a patient tailored ventilation while simultaneously ensuring a protective ventilation application.

\* "Smart Ventilation Control" is the software option for the Zeus® IE anaesthesia machine. For more information about availability, please contact your Dräger representative. [Smart Ventilation Control Video](#)



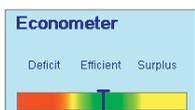
Smart Ventilation Control (SVC)

SVC was developed in co-operation with clinicians to simplify the application of protective ventilation regimes and to promote spontaneous breathing as early as possible and with the largest possible volume. SVC can provide classical mandatory ventilation. With SVC, it is possible to switch to different ventilation goals with a single interaction – e.g. promotion of spontaneous breathing using Pressure Support. SVC then reduces mandatory ventilation as soon as possible and may also gradually reduce Pressure Support to allow the patient to breathe spontaneously. SVC was developed with a focus on the workflow in anaesthesia in order to meet day-to-day requirements. Instead of various ventilation modes with a large number of different parameters (P<sub>insp</sub>, frequency, I:E...), users can determine directly the desired ventilation objective (e.g. "controlled" or "encourage spontaneous breathing"). This goal-oriented setting greatly reduces the number of operating steps required, and at the same time guarantees the maintenance of adequate tidal volumes and a stable level for end-tidal CO<sub>2</sub>. This aids the provision of high quality ventilation and helps reduce the cognitive workload.

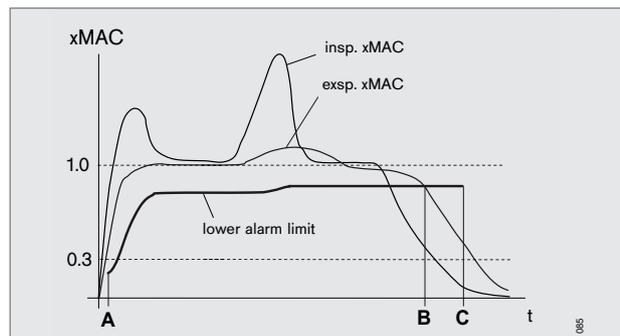
**Simple to use**

A standardised concept for use in all departments and for all devices increases operational safety and reduces the need for training and inservice. Furthermore, the Dräger anaesthesia machines are equipped with various assistance systems for minimising the required user interactions with the device and preparing and presenting the available data in a readily comprehensible form, so that users can better focus their attention on the patient and their cognitive workload is reduced.

One of them is the econometer with its qualitative "traffic-light" display of the efficiency of fresh gas use. If the fresh gas setting is more than 1 l/min above the current gas consumption, the econometer indicates "Surplus" (yellow). Below this value the fresh gas use is "Efficient" (green). If the gas consumption is higher than the fresh gas flow set, this results in a fresh gas "Deficit" (red), which then also triggers an alarm. The gas consumption is calculated from patient uptake, any circuit leakage occurring, and the volume of CO<sub>2</sub> taken up by the CO<sub>2</sub> absorber.



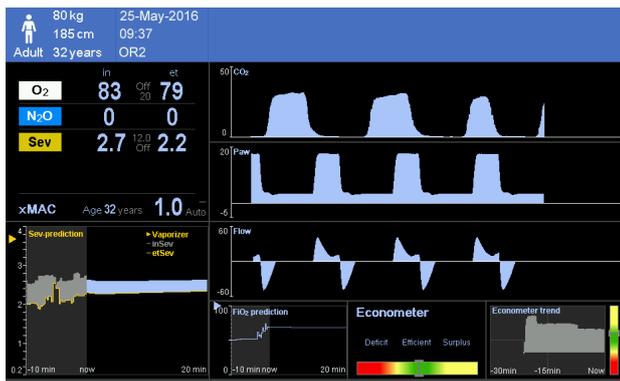
With the automatic xMAC monitoring the anaesthesia machines in the Primus®- and Zeus® families and the Perseus® A500 can offer a safety function helping to prevent an unintentional drop in the level of anaesthesia / concentration of volatile anaesthetic agent. The current expiratory anaesthetic gas concentration and N<sub>2</sub>O concentration derived from sidestream measuring close to the patient, and the patient's age, are used to calculate age-corrected xMAC values. The monitoring function is automatically activated as soon as the expiratory xMAC reaches a value of approx. 0.3 (A). After activation, an alarm limit adjusts itself automatically at a value approx. 70% of the current expiratory xMAC level. However, the alarm limit adjusts itself only to rising xMAC values. As soon as the expiratory xMAC value falls below the alarm limit (B), the message "Low MAC" is generated. By confirming the question "Low MAC OK?" users can cancel the alarm message (C). Cancelling the alarm in this manner adjusts the automatic xMAC monitoring such that during an intentional further reduction in the depth of anaesthesia, e.g. for emergence from anaesthesia, the alarm is not triggered again.



Operating principle behind the "Low MAC" alarm

**Predictive functions**

The Perseus® A500 offers intelligent predictive functions when used in conjunction with the Vapor 3000 and D-Vapor 3000 anaesthetic vaporisers. The machine calculates how the gas concentration will develop, based on the fresh gas settings, the handwheel position communicated by the Vapor, the patient's demographic data that have been entered, and the current measured gas values. The Perseus® A500 predicts both the inspiratory and the expiratory volatile-agent concentrations, and the inspiratory oxygen concentration. These features therefore offer higher levels of safety and transparency during anaesthesia. At the same time, the number of steps for the user is reduced and precise recovery is facilitated. The vaporisers are also equipped with visual alarms to support the user, and low vaporiser filling levels are indicated in good time by the Perseus® A500.



VaporView

### Auto control

The auto control function of anaesthesia machines in the Zeus® family provides the option of target-oriented control of fresh gas and anaesthetic gas. Users enter only the desired inspiratory oxygen concentration (FiO<sub>2</sub>) and the desired expiratory concentration of the volatile agent. The fresh gas and the volatile agent are dosed into the breathing system in parallel and therefore independently from each other. This enables the anaesthesia machines in the Zeus® family to operate in closed system mode, in which case only the patient uptake is replaced back into the system. The system thus at all times automatically selects the quantity of fresh gas to be as high as necessary but simultaneously as low as possible. This saves fresh gas - and especially volatile anaesthetic agent - in comparison with the classical semi-closed breathing systems. The anaesthesia systems have two redundant gas measuring benches so that no compromises in safety have to be made when using auto control.

### SmartPilot® View – visualisation of level of anaesthesia

SmartPilot® View calculates the full pharmacokinetics and pharmacodynamics of the anaesthetic agents administered, on the basis of the patient data entered by the user, and thus offers an additional information base for assessing the level of anaesthesia. In the field of pharmacokinetics, the effect concentrations of common opioid analgesics and volatile anaesthetics are calculated, along with those of propofol and various muscle relaxants. The machine displays the current effect concentration and a 20-minute prediction of the effect concentration for each medication. Changes in the dosage trigger recalculation. The pharmacodynamic display shows the combined effect of propofol / volatile anaesthetics and the opioid analgesics. The 2-D display showing the depth of anaesthesia enables rapid recognition of the combined effect and facilitates titration of the medication for each patient.

SmartPilot® View can also support early spontaneous breathing because the user has the development of the calculated effect concentration of the individual medications and the synergistic effect of hypnotics and opioids in view. This can help the user to estimate the effects of the level of anaesthesia and muscle relaxation on the respiratory drive and on the respiratory muscles, and to dose the medications so that spontaneous breathing becomes possible at the desired time.



SmartPilot® View

SmartPilot® View can be combined with products from the Primus®- and Zeus® families and with the Perseus® A500. Furthermore, SmartPilot® View is an software option of Zeus® IE anaesthesia systems as an application in the cockpit.

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