CASE REPORT

# Anesthesia | Ventilation performance

# In anesthesia... every measure matters

## – especially with pediatric patients

In pediatric anesthesia, small adjustments in mechanical ventilation may lead to large physiological changes. The accuracy of measured values becomes critically important as the size of the patient decreases, and the severity of illness increases.

Understanding the interactions between the respiratory and circulatory systems is essential for every anesthesiologist. Under normal conditions, the interactions between these organ systems are inconsequential. However, they may become exaggerated and of great importance in certain disease states and when each system is affected by general anesthesia.

Heart-lung interactions occur because the heart is encompassed by the lungs and both are encased within the chest wall, which is compliant in young children and rigid in adults. During normal spontaneous respiration, negative intrathoracic pressure is generated with inspiration, which enables air to enter the lungs but also increases venous return to the right side of the heart. With positive pressure ventilation, the opposite occurs, with a decrease in venous return to the right heart and hence a decrease in preload. In structurally normal hearts, less blood in the right ventricle leads to less blood in the left ventricle and less blood that can be pumped out, so decreasing cardiac output. This effect on venous return may be beneficial when used in patients with cardiogenic pulmonary edema. In these patients, who have volume overload, decreasing venous return will have the dual beneficial effect of decreasing preload and helping to put an often over distended left ventricle on a more favorable portion of the Frank-Starling curve. In addition to improving cardiac output, positive pressure ventilation improves the oxygen supply and demand relationship by reducing myocardial and respiratory muscle oxygen consumption.[1]

In certain disease states, the sudden change from spontaneous respiration to positive pressure ventilation can have negative consequences. For example, in hypertrophic cardiomyopathy, there is ventricular diastolic dysfunction and with the induction of general anesthesia and positive pressure ventilation, preload may be significantly reduced and result in further underfilling of the left ventricle. If left ventricular outflow tract obstruction is also present, reduced systemic vascular resistance, caused by many anesthetic agents, decreases left ventricular afterload, which when accompanied by a reduced preload may exacerbate intracavitary and ventricular outflow obstruction. Even after successful induction of anesthesia, finding an optimal PEEP to maximize both venous return to the right atrium, and prevent atelectasis, can be a challenge.


*Image of Flow-i in OR.*

## Clinical case from U.S. hospital

'Titus' is a 4-year-old boy, who weighs 12 kg, with severe, progressive idiopathic hypertrophic cardiomyopathy and failure to thrive. He has been waiting for a heart transplant for six months, and a donor match has been found for him. His pre-operative echocardiogram demonstrates a severely hypertrophied left ventricle with hyperdynamic systolic function, impaired diastolic relaxation with mid-cavitary obliteration during systole. The right ventricle is of normal size and demonstrates good function. Titus' current medications include a calcium channel blocker, and he has no known drug allergies. The patient was admitted to the hospital from home the evening of transplant. Blood was drawn for routine laboratory analysis, including a cross match for blood products. Unfortunately, peripheral intravenous access could not be achieved due to difficult venous access and lack of patient cooperation.

Twenty minutes prior to the scheduled operating room start time, an oral premedication of midazolam was administered. The patient was then taken to the operating room, and routine monitors were applied. Due to the difficulty with peripheral intravenous access, a mask inhalational induction of anesthesia was performed as follows; the patient received a step wise increase in sevoflurane concentration to a maximum of 6% volume in a mixture of oxygen and nitrous oxide. As soon as the patient was asleep, the sevoflurane concentration was reduced to 3% and peripheral intravenous access was rapidly secured in the left saphenous vein. Intravenous rocuronium and fentanyl were then administered to facilitate oral intubation and the fractional inspired oxygen concentration was increased to 0.8. At the time of intubation, the 'Pause gas flow' function was used on the Flow-i® anesthesia machine to prevent room contamination with sevoflurane *(see Figure 1)*.

A cuffed 4.5 mm oral endotracheal tube was placed and the position was successfully confirmed with bilateral breath sounds and the presence of end tidal carbon dioxide. An endotracheal tube leak test was performed to ensure a leak was present with the endotracheal tube cuff deflated and then using the manometer feature on the Flow-i anesthesia machine, the cuff was inflated to a leak pressure of 20 cm $H_2O$ *(see Figure 2)*.


Figure 1 Pause gas flow feature.

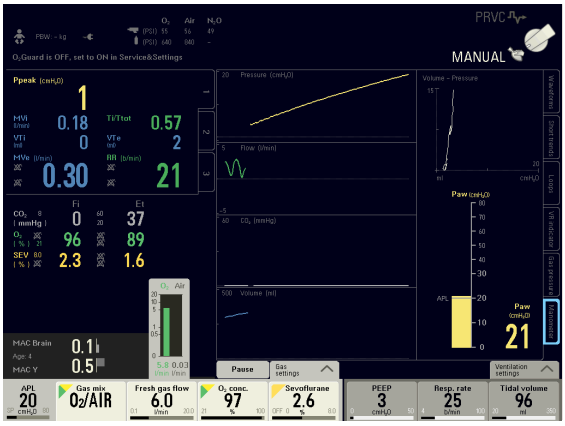


Figure 2 Manometer feature

The patient was then placed on a 'pressure regulated volume controlled' (PRVC) mode of ventilation using the preset values which were entered prior to the patient coming into the operating room *(see Figure 2)*. Particular attention was paid to setting the tidal volume to 8ml/kg and the positive end expiratory pressure (PEEP) to 0 cm $H_2O$ (Zero PEEP or ZEEP), in order to maximize preload to the heart and so maintain cardiac output under positive pressure ventilation. Using the quick access feature, the inhalational agent was changed from sevoflurane to isoflurane in keeping with our standard practice for long operations *(see Figure 3)*. The MAC-Y and MAC Brain feature on the Flow-i® anesthesia machine were then used to guide the depth of anesthesia and facilitate a downward titration of the fresh gas flow rate from 3 lpm to 1 lpm.

To maintain adequate preload, a fluid bolus of 20 ml/kg of normal saline was administered intravenously, while a right radial arterial catheter, a double lumen right internal jugular vein catheter and an additional peripheral intravenous catheter were placed. After approximately 45 minutes, the patient was ready for open heart surgery.

As this was the patient's first heart surgery, the surgeon was able to quickly perform a sternotomy and place Titus on cardiopulmonary bypass. During this process, the donor heart arrived in the operating room, in a cool box. The surgical assistant prepared the donor heart on a sterile table while the surgeon removed Titus' abnormal heart. The new donor heart was then successfully transplanted into the patient. After two hours on cardiopulmonary bypass the patient was slowly rewarmed. During this rewarming period, the patient's lungs were first suctioned to make sure no blood or secretions were present, and then a recruitment maneuver on the Flow-i® anesthesia machine was performed to ensure the lungs were fully inflated. Full ventilation was then resumed, with ventilation settings of a PEEP of 5 cm $H_2O$ to prevent atelectasis and a tidal volume of 8 ml/kg. To facilitate donor heart function, epinephrine and milrinone were continuously infused and the heart was paced

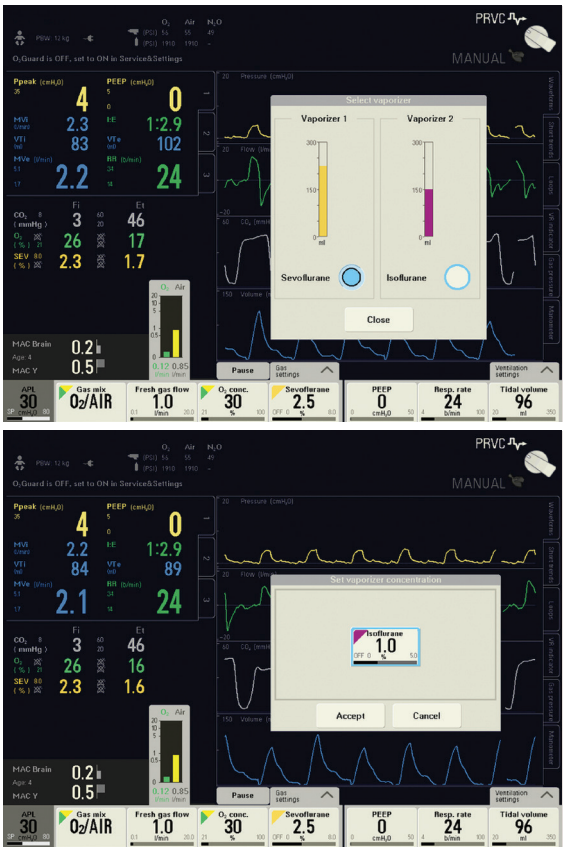


Figure 3 Changing electronic vaporizers using the touch screen.

at a rate of 100 beats per minute, using temporary pacing wires. The patient was successfully separated from cardiopulmonary bypass and the donor heart demonstrated good function. Hemostasis was achieved with heparin reversal using protamine and blood products. After a total of 5 hours in the operating room, the patient was transferred to the cardiac intensive care unit for further management. The ventilator in the intensive care unit was a Servo-u® (Getinge, Sweden) and similar settings from the Flow-i anesthesia machine were used to initiate ventilation.

## Discussion

This case highlights some of the advanced features of the Flow-i® anesthesia machine and how they facilitate safe clinical care of a critically ill patient. One key feature of the Flow-i is its ability to deliver ZEEP. Often when PEEP is set to 0 cm $H_2O$, there is residual resistance in the anesthesia circuit, and this can result in low levels of PEEP.[2] This may be problematic when residual PEEP impairs venous return to a struggling, sick heart.

The quick access features such as pausing fresh gas flow during intubation, presets for fractional inspired oxygen concentration, fresh gas flow and changing inhalational agent are welcome short cuts for an anesthesiologist working to prepare a critically ill patient for surgery. These features enable a smooth, safe workflow.

The Flow Family of anesthesia machines and their innovative flow core anesthesia technology are designed to promote efficient gas usage, providing the power and precision to ventilate even the most challenging patients. This is due to the combination of the volume reflector and the servo gas modules, adjusting pressure and flow constantly with every breath. This highly accurate ventilation performance delivers intensive care unit (ICU) level of ventilation and enables parameters set for ventilation in the operating room to be accurately used to transition ventilation in the ICU.

Atelectasis affects over 90% of patients undergoing surgery, regardless of age, gender or length of surgery.[3,4,5] Lung recruitment is essential to counter atelectasis, improve oxygenation and prevent postoperative complications. What was once an unmeasured, manual process of 'recruiting' the lungs has now been optimized, measured and safely automated as a 'step wise' process on the Flow-i anesthesia machine *(see Figure 4)*. Throughout the recruitment maneuver, end inspiratory pressure (EIP), dynamic compliance (Cdyn) and PEEP are displayed breath-by-breath in real time enabling the clinician to assess the changes in a patient's lung compliance[6]. A lung recruitment maneuver has been shown to be the most effective method to improve post-bypass oxygenation in children.[7]

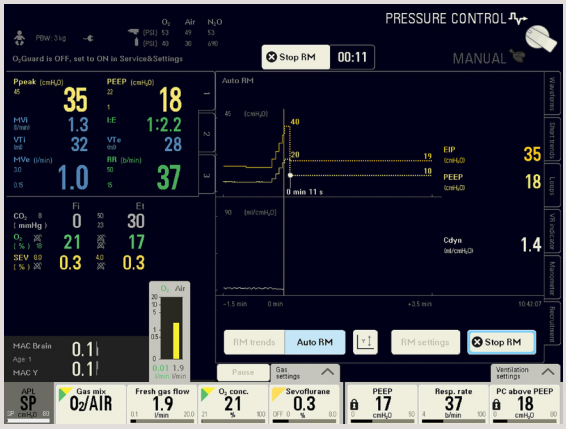


Figure 4 Stepwise recruitment maneuver.

The MAC Brain feature enables a precise control of depth of anesthesia. The tool visualizes the difference in agent concentration between the lung, and the target organ, the brain. Due to the pharmacokinetics of inhalational anesthetic agents, there is a time delay in agent concentration between the end-tidal MAC, called MAC-Y (for Y-piece where it is measured) and the brain.[8] The patient's MAC-Brain is derived from an algorithm based on pharmacokinetic models, and it provides a visual number for the clinician to help guide anesthetic agent dosing. This is particularly helpful during induction of anesthesia until a steady state is reached, and during the rewarming phase of cardiopulmonary bypass when ventilation is restored and awareness under anesthesia is a known risk.

Another advanced feature for the Flow Family of anesthesia machines, is the digital service Getinge Online. This service connects all anesthesia machines in a facility to an online portal, which enables both service teams and clinicians to maximize uptime, gain insights and improve efficiency. With busy operating rooms, which must be available **all** the time, it is essential to maximize the safe operation of the anesthesia machine. This can be done by local service technicians working together with Getinge technical experts, who may be in a remote location.

Every person undergoing surgery with anesthesia depends on the reliable, continuous, safe operation of the anesthesia machine. Many insights may be gained from the data collected and over time with a fleet of anesthesia machines it is possible to see trends, which can be acted on to change anesthesia provider behaviors. For example, encouraging anesthesia providers to use advanced anesthesia machine features such as pausing fresh gas flow during intubation, and lowering fresh gas flows throughout a case, can reduce inhalational anesthetic agent usage. Every small change adds up to a large cost saving for the hospital in anesthetic agent usage and protecting the environment.[9]

Less than 24 hours after receiving his new heart, Titus was successfully weaned from the ventilator and supportive inotropic therapy. Today he is a young boy, full of energy and enjoying life. Getinge with their advanced Flow Family of anesthesia machines, played a critical role in helping Titus through his heart transplant and protecting his future world.

## References


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This case study highlights one clinician's use of the Flow-i® and certain features in a clinical setting. Clinical practice and device settings are not recommended, and may vary by facility. Patient results may not be typical. Visit https://info.getinge.com/flow-i-case-studies and www.getinge.com to learn more about the products and see other case studies.

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Indications for use: The indication for Flow-i Anesthesia System is administering inhalation anesthesia while controlling the entire ventilation of patients with no ability to breathe, as well as in supporting patients with a limited ability to breathe. The system is intended for use on neonatal to adult patient populations. The system is intended for use in hospital environments, except MRI environments, by healthcare professionals trained in inhalation anesthesia administration.


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