CASE REPORT

Anesthesia | Ventilation performance

Neonatal intensive care in the OR with the Flow-i anesthesia machine

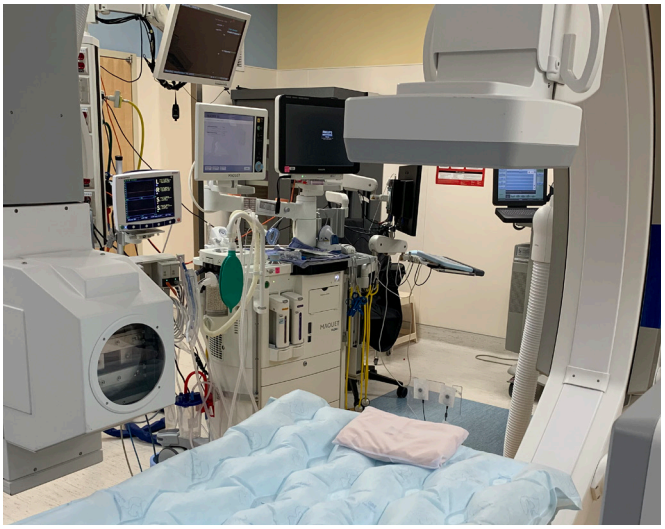
Continuity of protective mechanical ventilation in the US

– from neonatal intensive care unit to cardiac catheterization laboratory

Advanced, high-performance ventilation capabilities of Getinge's Flow-i anesthesia machine have helped to ventilate and anesthetize very low birth weight and premature neonates.

Mechanical ventilation is a life-saving therapy and cornerstone of the modern-day intensive care unit. The capabilities of a ventilator are often revealed at the extremes of age and weight. Premature, very low birth weight neonates are probably the most medically fragile patients in any hospital, and they present a ventilation challenge. These infants are at very high risk of adverse, anesthesia-related events largely due to their respiratory physiology. One-third of all perioperative cardiac arrests in pediatric anesthesia are related to the respiratory system.[1]

Neonatal intensive care units (NICU) have focused on lung protective ventilation strategies to avoid ventilator-induced lung injury in an effort to reduce the severity of chronic lung injury.[2] In addition to requiring prolonged mechanical ventilation, vulnerable neonates often require procedural interventions for either congenital or acquired problems. Examples of each are congenital diaphragmatic hernia repair and exploratory laparotomy for necrotizing enterocolitis. Traditionally it has been advantageous to perform surgical procedures at the bedside in preterm neonates due to the continuation of mechanical ventilation with a dedicated neonatal ventilator, and the avoidance of problems during transport from the neonatal intensive unit to the operating room. Other advantages of remaining in the NICU may include better temperature control, maintenance of fluid and inotropic therapy and engaging the expertise of the neonatologist, respiratory therapist and nursing staff. However, bedside procedures have limitations for the surgical and anesthesia teams who have to bring equipment and supplies into a small patient room and unfamiliar environment. Furthermore, certain procedures have to be done where there is specialized equipment, such as the fluoroscopy capabilities of the cardiac catheterization laboratory. Fortunately, the advanced high-performance ventilation capabilities of Getinge's Flow-i anesthesia machine have now helped us ventilate and anesthetize very low birth weight and premature neonates. This has made it possible to move a fragile preterm neonate from the NICU to another location for a procedure.



Catheterization laboratory with Flow-i anesthesia machine.

US Case Report

Baby girl 'Hope' was born as twin B at 24 weeks gestation due to maternal preterm labor. No antenatal steroids were received by the mother prior to delivery. The birth weight was 770 gms and the baby was intubated in the delivery room with an uncuffed 2.5 mm orotracheal tube and placed on conventional mechanical ventilation. On day of life (DOL) 2, Hope had a pulmonary hemorrhage and was transitioned to high frequency oscillatory ventilation (HFOV). Hope had a period of stability on the ventilator, requiring only low dose inotropic support with dopamine, but then developed abdominal distension after one week. On DOL 9 an abdominal X-ray revealed pneumatosis of the bowel wall and free air in the abdomen. This raised concerns for necrotizing enterocolitis complicated by bowel perforation. Hope underwent an exploratory laparotomy which revealed distal ileal bowel perforation which required a small segment bowel resection and ileostomy creation. Following her abdominal surgery, Hope remained on HFOV and slowly recovered. However, during her recovery it was noted on echocardiogram that she had a large patent ductus arteriosus (PDA). A trial of acetaminophen was begun in an attempt to close the PDA. However, repeat echocardiogram on DOL 17 still revealed a large PDA, with continuous unrestrictive left to right shunting across the PDA with a maximum velocity of 1.8 m/s and a peak gradient of 12 mmHg. The left to right shunting through the PDA was described as 'torrential' with enlargement and hyperdynamic function of the left heart and a severely dilated left atrium. The right ventricle was normal in size and function. After discussions with the interventional cardiologist and cardiac anesthesiologist, it was decided that closure of the PDA with a device in the cardiac catheterization laboratory would likely improve the cardiac and pulmonary status of the patient. As Hope had made significant respiratory improvements it was suggested by the neonatologist to transition the baby from HFOV to conventional ventilation. The night prior to going to the cardiac catheterization laboratory the baby was successfully transitioned to conventional ventilation using Getinge's Servo-n ventilator in PRVC mode *(see Table 1)*.

Table 1 **Ventilation mode, parameters and arterial blood gas timeline**

Time in relation to PDA closure in the cardiac catheterization lab	NICU : Night before procedure	NICU: Morning of procedure	During procedure	Following procedure in the NICU
Age (Day of Life)	18	19	19	19
Ventilator /mode	HFOV	Servo-n/PRVC	Flow-i/PC	Servo-n/PRVC
Settings	F 10Hz , A 17, MAP 12	TV 5ml, RR 38, PEEP 6, PIP 20	TV 8ml, RR 26, PEEP 5, PIP 21	TV 5ml, RR36, PEEP 6, PIP 21
FiO_2	0.5	0.46	0.49	0.5
ABG:				
pH	7.26	7.31	7.40	7.30
PaO2	66	61	65	61
PaCO2	53	51	43	59
HCO3	32	33	27	31
BE	3	5	2	4

HFOV: High Frequency Oscillatory Ventilation
F: Frequency
A: Amplitude
MAP: Mean Airway Pressure
TV: Tidal Volume
RR: Respiratory Rate
PEEP: Positive End Expiratory Pressure
PIP: Peak Inspiratory Pressure
ABG: Arterial Blood Gas

On the morning of the proposed PDA closure, the cardiac catheterization lab was prepared as follows:

- Full system checks performed on Getinge's Flow-i anesthesia machine, with an infant circuit attached and extended to an appropriate length.
- Endotracheal tube connector; low dead space adapter 2.5mm with side port for end tidal carbon dioxide sampling available.
- Anesthesia medications and emergency medications, appropriately diluted and drawn up into syringes and ready to use.
- Room and bed warmed.

The patient was re-evaluated prior to transport to the cardiac catheterization lab. Vascular access included a 1.1Fr single lumen percutaneous central line in the right saphenous vein, a 24 G left radial arterial line and a 24 G peripheral intravenous catheter in the right arm. After a systematic handover of care with the NICU team, the patient received intravenously administered fentanyl and rocuronium prior to transport to ensure the vital signs remained stable in the NICU setting. The patient was transported to the lab in the infant warmer and ventilated with the Servo-n ventilator on battery power. Oxygen and air cylinders enabled the FiO_2 to be kept at 0.45 during transport.

On arrival in the cardiac catheterization lab, the baby was carefully moved to the procedure table and connected to the Flow-i anesthesia circuit with minimal interruption in ventilation. The anesthesia machine was able to closely mimic the settings of the Servo-n ventilator *(see Figure 1)* and adequate ventilation was confirmed on an arterial blood gas at the start of the procedure. The zero dead space adapter placed on the endotracheal tube enabled accurate waveforms and end tidal carbon dioxide to be detected. Low fresh gas flows were used with low dose isoflurane administered at 0.4 Vol% during the case. No additional medications were given except for heparin at the time of vascular access and antibiotics when the duct occluder device was deployed.

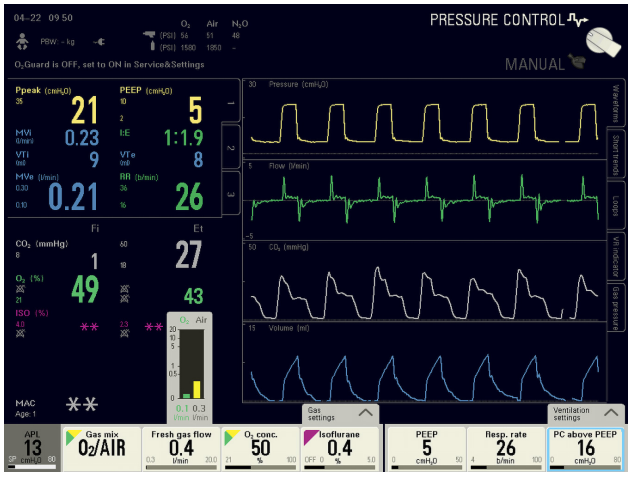


Figure 1. Anesthesia machine monitor readings (Flow-i).

After appropriate preparation of the patient's femoral area and sterile draping, the procedure started with ultrasound guided placement of a 4Fr sheath in the right femoral vein. With a combination of trans-thoracic echocardiography and fluoroscopic guidance, an Amplatzer Duct Occluder II 4/2 mm device (Abbott, IL USA) was successfully placed in the PDA. There was a corresponding increase in diastolic blood pressure and narrowing of pulse pressure consistent with reduced flow across the PDA. An echocardiogram and contrast study at the end of the procedure both confirmed successful complete occlusion of the PDA, with no disturbance to blood flow in the pulmonary artery or aorta from the device placement. The entire procedure time was 31 minutes with a fluoroscopy time of 5 minutes. The patient was transported back to the NICU on the Servo-n ventilator and report given to the NICU team. At the time of handover, all of the patient's vital signs were stable, the ventilation parameters were unchanged, and the temperature was 36.8°C.

Discussion

This case report demonstrates that extremely premature and low birth weight infants can be safely transported and cared for in procedural settings outside of the NICU. Such procedures are frequently needed.

In this example, the incidence of PDA in preterm neonatal patients is up to 70%, with an inverse relationship to birth weight. In very low birth weight babies the likelihood of spontaneous closure is less than 15%.[3] Failure of ductal closure leads to a left-to-right shunt which can result in pulmonary over circulation and left heart volume overload. Delayed closure of the PDA in low birth weight babies has been associated with chronic lung disease, necrotizing enterocolitis and pulmonary hypertension.

Pharmacological attempts to close the duct with medications, such as indomethacin and acetaminophen, have an estimated closure rate of 50%. Given their vasoconstrictive properties, these medications have been associated with renal insufficiency and intestinal perforation. Despite advances in surgical techniques, surgical duct ligation has largely fallen out of favor due to early and long-term complications. Transcatheter PDA closure offers the medically fragile neonate an alternative path when pharmacological therapies fail.[4]

The seamless transition of ventilation from the Servo-n ventilator to the Flow-i anesthesia machine has made it possible to safely ventilate neonatal patients and maintain lung protective ventilation strategies. Modern anesthesia ventilators are better suited to ventilating very small patients due to advanced microprocessor technology which enables precise control over pressure, volume and time, as well as the introduction of features such as circuit compliance compensation. There is commonly a small discrepancy in ventilation parameters between the NICU ventilator and anesthesia machine because of where measurements are made. Anesthesia machines have internally positioned flowmeters as opposed to an ICU ventilator which may have a flow meter attached to the end of the patient circuit. Most neonatal ventilators control expiratory tidal volume which allows them to operate with a significant leak which is common with uncuffed endotracheal tubes used by many NICUs.[5]

An innovative and unique feature of the Flow-i anesthesia machine is the Volume Reflector which allows precise calculation and delivery of volumes due to the constant internal volume of the rigid Volume Reflector. This technology replaces traditional 'bellows' and piston-operated systems. The Volume Reflector never empties and maintains accuracy during low-flow and low-minute ventilation anesthesia, even when a leak is present.[6]

The Servo-n and Flow-i ventilators have the same gas modules which contribute to the high ventilation accuracy of the anesthesia machine. Now, for the first time, anesthesiologists have the ability to provide ICU level ventilation to extremely premature and low birth weight babies, with the advantage of delivering inhalational anesthetic agents in a safe system. This enables a balanced anesthetic technique for all patients and avoids the risk of adapting an ICU ventilator to administer inhalational anesthetic agents when high fidelity ventilation is needed in the most challenging patients.[7]

Flow-i anesthesia machine

References

1. Bhananker SM, Ramamoorthy C, Geiduschek JM, et al. Anesthesia-related cardiac arrest in children: update from the Pediatric Perioperative Cardiac Arrest Registry. *Anesth Analg.* 2007;105(2):344-350.
2. Neumann RP, von Ungern-Sternberg BS. The neonatal lung--physiology and ventilation. *Paediatr Anaesth.* 2014;24(1):10-21.
3. Clyman RI. Patent ductus arteriosus, its treatments, and the risks of pulmonary morbidity. *Semin Perinatol.* 2018;42(4):235-242.
4. Almeida-Jones M, Tang NY, Reddy A, Zahn E. Overview of transcatheter patent ductus arteriosus closure in preterm infants. *Congenit Heart Dis.* 2019;14(1):60-64.
5. Burstal RJ, Threlfo SJ. Delivery of sevoflurane using a neonatal ventilator. *Paediatr Anaesth.* 2018 Sep;28(9):774-779.
6. Lucangelo U, Ajčević M, Accardo A, et al. FLOW-i ventilator performance in the presence of a circle system leak. *J Clin Monit Comput.* 2017;31(2):273-280.
7. Petak F, Habre W. MacGyver or Machiavellian approaches to delivery of sevoflurane in neonates. *Paediatr Anaesth.* 2018;28(9):756-757.

The views, opinions and assertions expressed are strictly those of the contributing clinician and do not necessarily reflect or represent the views of Getinge AB or Maquet Critical Care AB. The contributing clinician was not paid or compensated by Getinge AB or Maquet Critical Care AB.

GETINGE

Sales Office • Getinge • 1 Geoffrey Way • Wayne, NJ 07470 ·USA
Manufacturer • Maquet Critical Care AB • Röntgenvägen 2 SE-171 54 Solna • Sweden • +46 (0)10 335 73 00

www.getinge.com

MCV00106365 REVA
EXP 08/22