How to Manage Mechanical Ventilation When Using the Universal Portable Anesthesia Complete Vaporizer, 26 Dec 2021

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Photos courtesy of Medical Photography, San Antonio Military Medical Center, Ft. Sam Houston, TX

I. Introduction

A. *This Clinical Practice Guideline (CPG) will clearly demonstrate in a step-by-step fashion the proper setup of the UPAC to each of the fielded ventilators, allowing anesthesia providers across all services to deliver safe, effective anesthesia to our warfighters.*

B. Anesthesia providers in Forward Resuscitative Surgical Teams (FRSTs) have relied on the Impact Uni-Vent Eagle 754 ventilator (Impact 754) to manage mechanical ventilation when using the Universal Portable Anesthesia Complete (UPAC) vaporizer. In support of modernizing forward surgical care, including the deployment of FRSTs, the military now fields new ventilators across the services. These ventilators include the Impact Uni-Vent 731 (Impact 731), HAMILTON T-1, and SAVe II. The Impact 731 and HAMILTON-T1 are the most readily available to FRSTs. While the SAVe II is available to some FRSTs, it is not recommended for long-term use and should only be used when other ventilators are not available. It is likely that many anesthesia providers have not worked with these new ventilators, and do not have the knowledge or access to reliable references/resources on the proper mating of the UPAC to a specific ventilator.

C. The CPG will follow a simple, easy to read format devoid of extraneous details. Each ventilator will have a section detailing complete start-to-finish setup of the UPAC to the ventilator. There will be detailed, labeled photographs with captions to assist the reader. Additionally, there will be troubleshooting tips at the end of each ventilator's section when applicable.

D. This CPG will serve as an invaluable resource to military anesthesia providers at home and abroad. There is no other known resource of its kind available to date, and it is a resource that can be easily adapted and utilized in the ever changing operational domain. The CPG will equip anesthesia providers with the knowledge and confidence to provide the highest quality care possible and assist our service members return to the fight.

II. UPAC Draw-Over Vaporizer

A. Standard equipment

Figure 1. Disassembled UPAC components. 1) UPAC case 2) UPAC vaporizer 3) Facemask 4) UPAC patient circuit tubing 5) Oxygen concentrator tubing and self-inflating bag tubing 6) T connector 7) Oxygen reservoir dust cap 8) Unidirectional E valve 9) Self-inflating bag 10) Oxygen tubing

Comments: Disassembled UPAC standard components

Figure 2. UPAC basic set

Comments: The UPAC vaporizer, UPAC patient circuit tubing, oxygen tubing, and facemask are known as the basic set. The basic set is required for use with each ventilator. Note that the oxygen concentrator and self-inflating bag tubing, T connector, oxygen reservoir dust cap, unidirectional E valve, and self-inflating bag from Figure 1 are not required items when using the UPAC with a ventilator. If positive pressure ventilation is needed without using a ventilator, use a separate self-inflating ventilation device (Ambu-bag) after disconnecting the patient from the UPAC-ventilator circuit.

Figure 3. Basic set with vaporizer oxygen inlet attached. 1) Supplemental oxygen connection.

Figure 4. UPAC vaporizer. 1) Vaporizer inlet 2) Concentration dial 3) Vaporizer outlet 4) Universal concentration chart 5) Supplemental oxygen inlet 6) Liquid anesthetic site glass 7) Fill port 8) Vaporizer stand

Comments: UPAC vaporizer details. When using the UPAC in a push-through configuration (as demonstrated in all four ventilator cases) the UPAC patient circuit tubing from the basic set is connected to the vaporizer inlet (Figure 4-1) and the standard ventilators' patient circuits are attached to the vaporizer outlet (Figure 4-3). C-clamps are also needed to secure the vaporizer stand to the work surface due to the top heavy nature of the vaporizer.

III. Impact 754 Ventilator

A. Required equipment

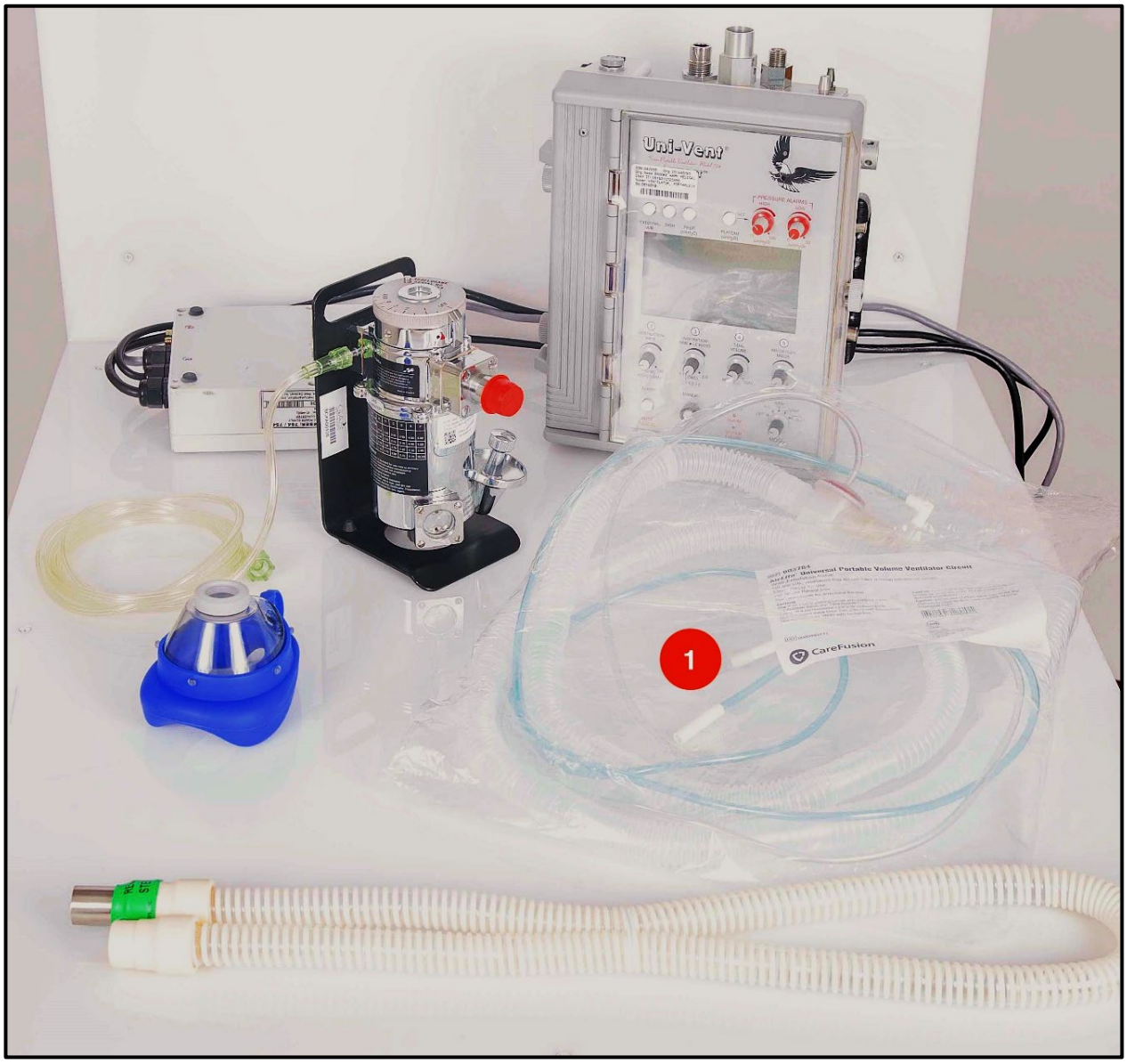


Figure 5. Impact 754 ventilator standard equipment set with patient circuit and UPAC basic set.
1) Patient circuit

Comments: The Impact 754 ventilator circuit will function with the Impact 731 and SAVe II ventilators.

Figure 6. Impact 754 power source. 1) Power connection for ventilator

Figure 7. Top view of Impact 754. 1) Attachment for standard circuit expiratory check valve 2) Attachment for standard circuit pressure transducer 3) Attachment for UPAC patient circuit tubing from the basic set

Comments: The UPAC patient circuit tubing from the basic set will connect to the vaporizer inlet (Figure 4-1).

Figure 8. Top view of patient connections for Impact 754. 1) Expiratory check valve tubing connected (clear tubing) 2) Pressure transducer tubing connected (blue tubing) 3) UPAC patient circuit tubing from the basic set

Comment: The pressure transducer tubing (blue) should be a different color than the expiratory check valve tubing (clear). The expiratory check valve tubing also has a textured collar at the end. If using

pipeline supply oxygen (55 psi standard) to the Impact 754, the auxiliary oxygen inlet on the UPAC (Figure 4-5) must remain occluded during use.

B. Connection to UPAC

Figure 9. Connection of UPAC patient circuit tubing from the attachment for UPAC patient circuit tubing from the basic set to the vaporizer inlet (Figure 4-1)

Comment: The UPAC patient circuit tubing metal-fitting end will connect to the vaporizer inlet.

C. Waste anesthetic gas scavenger setup

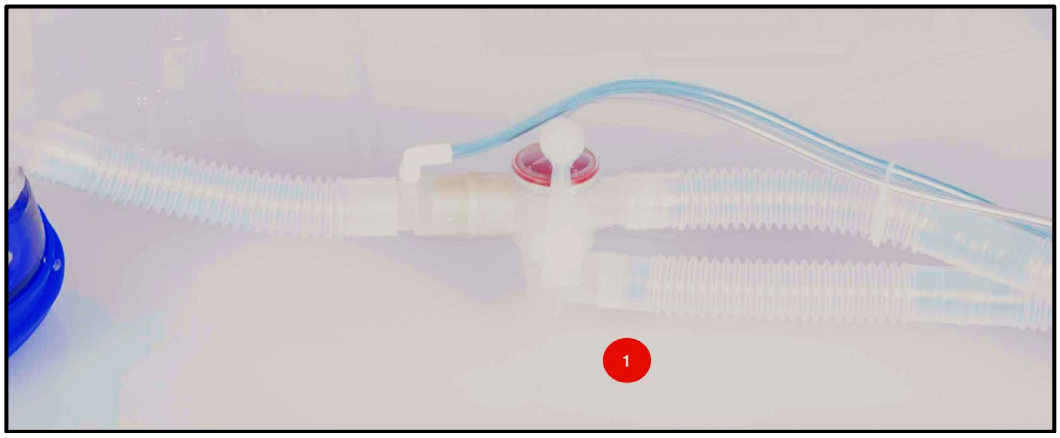


Figure 10 Waste anesthetic gas tubing connection to expiratory check valve of standard Impact 754 circuit. 1) Waste anesthetic gas tubing connection

Comments: Any standard diameter respiratory tubing (22mm female connection) will fit onto the swivel adapter directly beneath the expiratory check valve. This scavenger tubing should be routed out of the OR area, and *not* attached to any direct suction source (maintain passive waste anesthetic gas scavenging). Recommend using wire mesh or the standard UPAC dust cap (Figure 1-7) to prevent debris or insects from entering and occluding waste anesthetic gas tubing.

D. Full setup

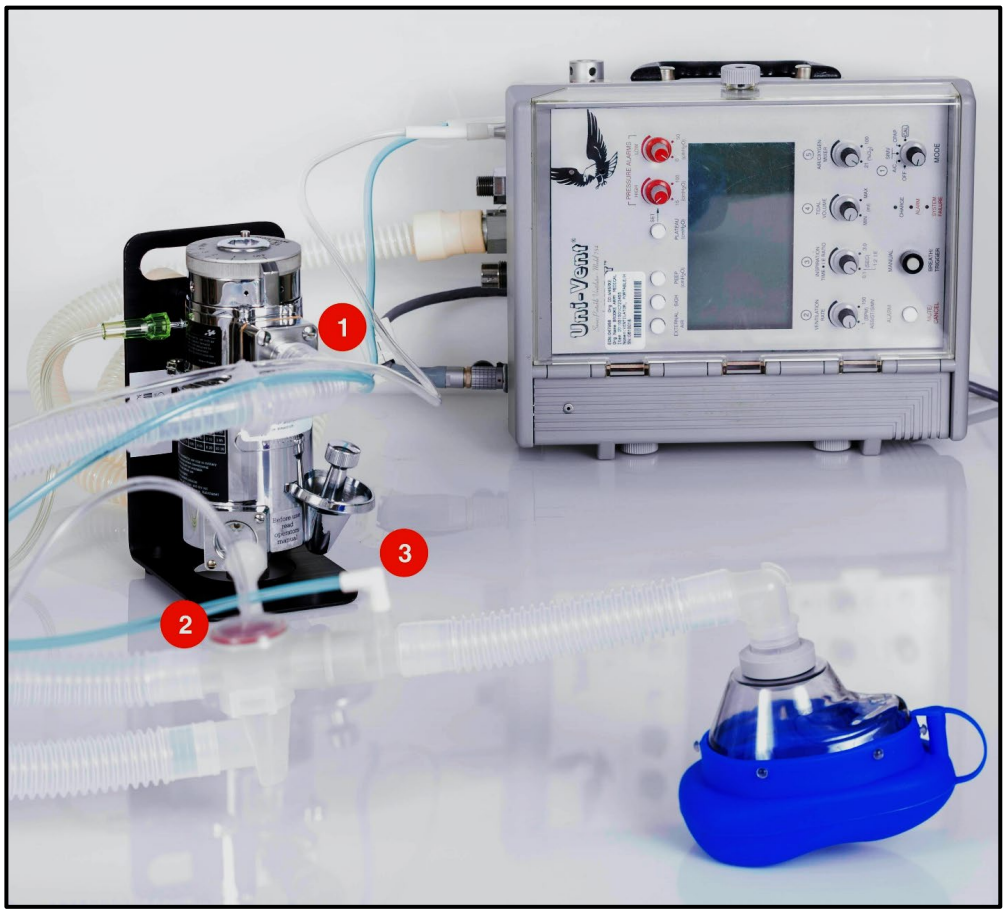
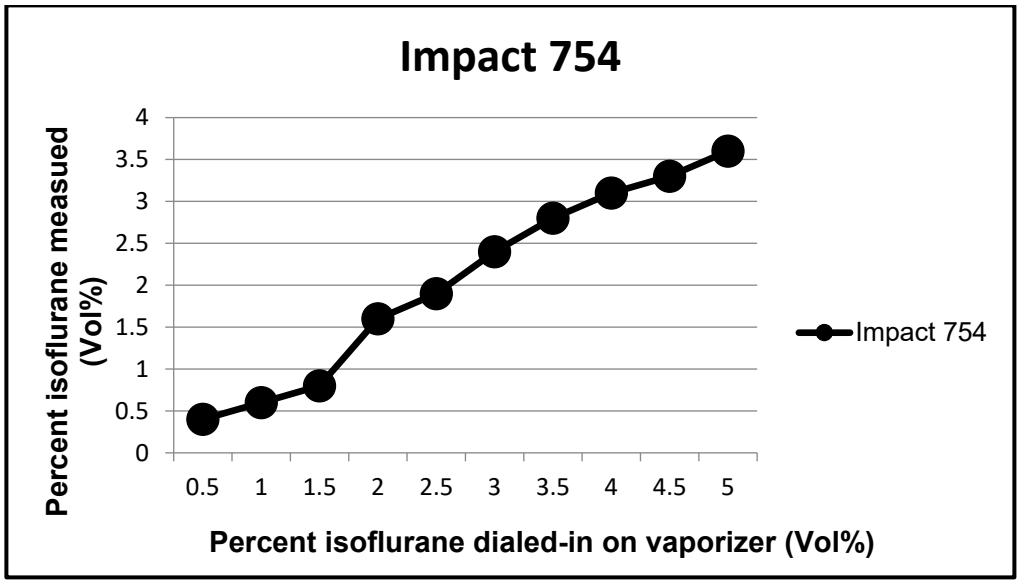


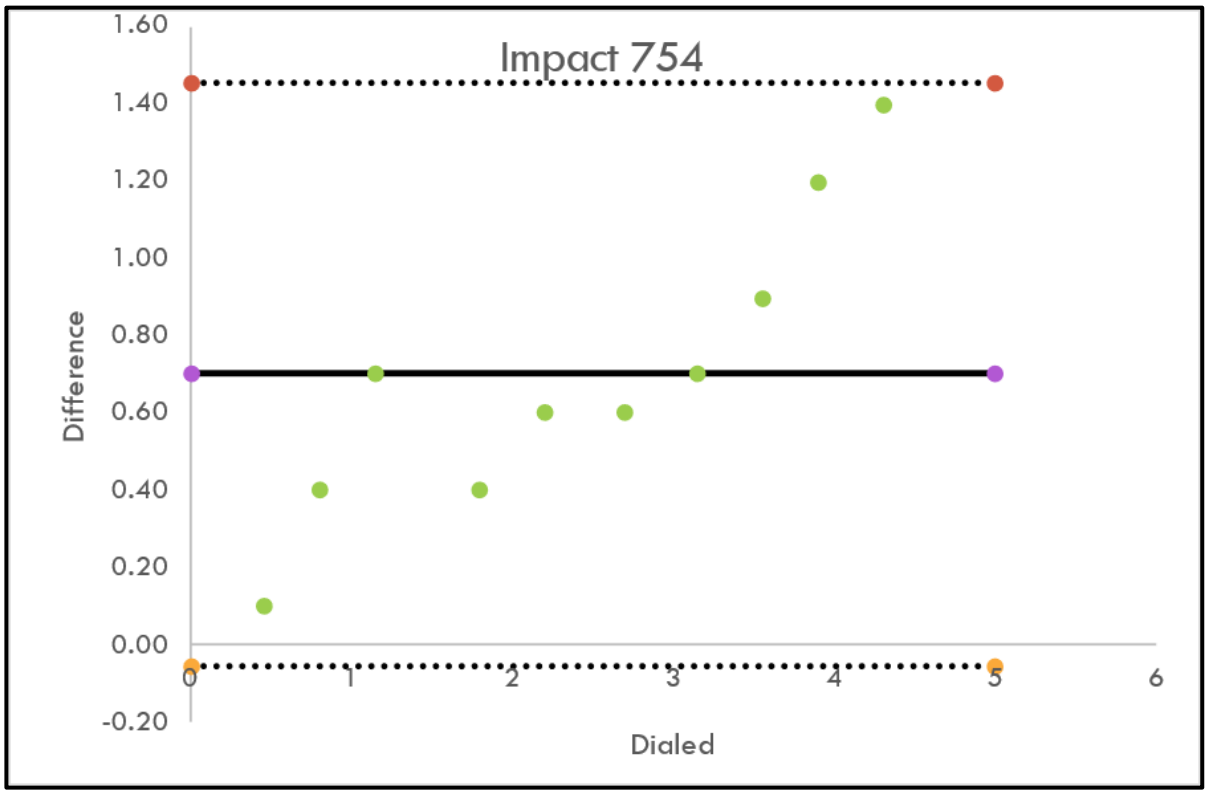
Figure 11. Complete setup of Impact 754 with UPAC. 1) Impact 754 circuit connected to UPAC outlet 2) Expiratory check valve 3) Pressure transducer

Comments: None

E. Expected UPAC vaporizer delivered agent concentrations (isoflurane shown)



F. Bland-Altman curve graph for isoflurane



G. Troubleshooting

Due to the limited visibility of the Impact 754 LCD screen, the use of a head lamp or flashlight is strongly encouraged. An external light source is not included in any discussed equipment set.

IV.Impact 731 Ventilator

A. Required equipment

Figure 12. Impact 731 ventilator. 1) Impact 731 2) Power cord 3) Standard Impact patient circuit and UPAC basic set

Comments: None

Figure 13. Top view of patient connections for Impact 731. 1) Power connection 2) Attachment for UPAC patient circuit tubing from the basic set 3) Attachment for standard circuit expiratory check valve 4) Attachment for standard circuit pressure transducer

Comments: None

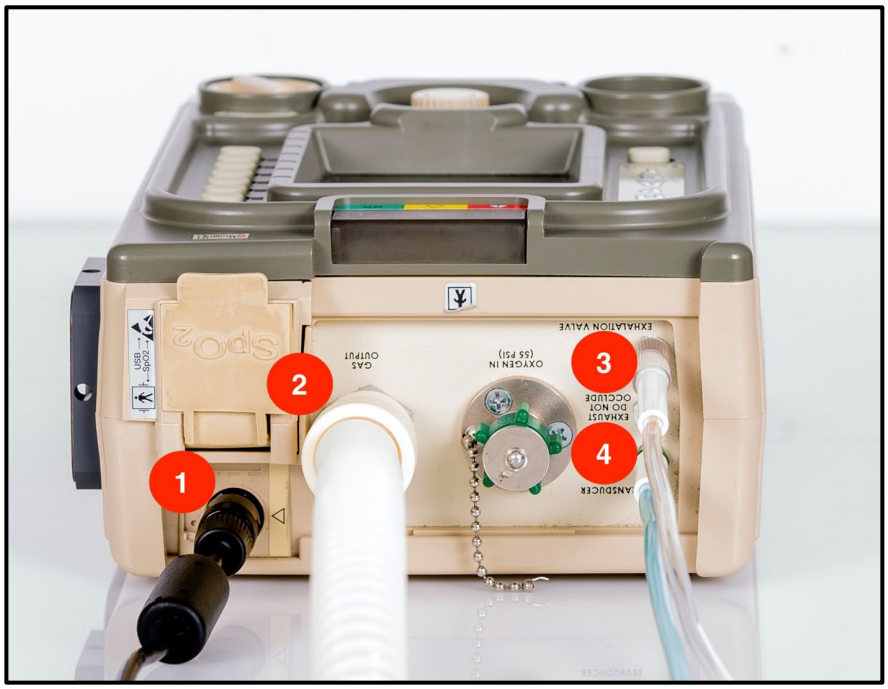


Figure 14. Top view of patient connections for Impact 731. 1) Power cord connected 2) Outlet connection to vaporizer via UPAC patient circuit tubing from the basic set 3) Expiratory check valve tubing connected (clear tubing) 4) Pressure transducer tubing connected (blue tubing)

Comments: As with the Impact 754, the pressure transducer tubing (blue) should be a different color than the expiratory check valve tubing (clear) on the Impact 731. The expiratory check valve tubing also

has a textured collar at the end. If using pipeline supply oxygen (55 psi standard) to the Impact 731, the auxiliary oxygen inlet on the UPAC (Figure 4-5) must remain occuded during use.

B. Connection to UPAC

Figure 15. Connection of UPAC patient circuit from the basic set (Figure 7-3) from the Impact 731 ventilator outlet (Figure 13-1) to the UPAC vaporizer inlet (Figure 4-1)

Comment: The UPAC patient circuit tubing metal-fitting end will connect to the vaporizer inlet.

C. Waste anesthetic gas scavenger setup

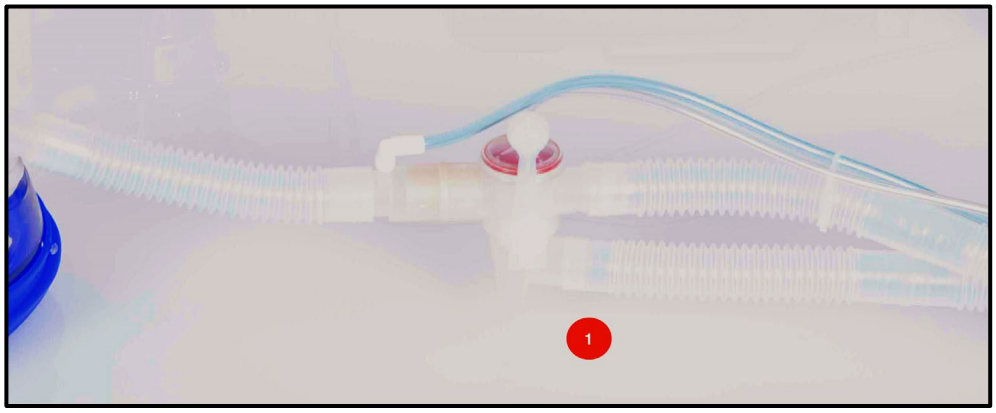


Figure 16. Waste anesthetic gas tubing connection to expiratory check valve of standard Impact 731 circuit. 1) Waste anesthetic gas tubing connection

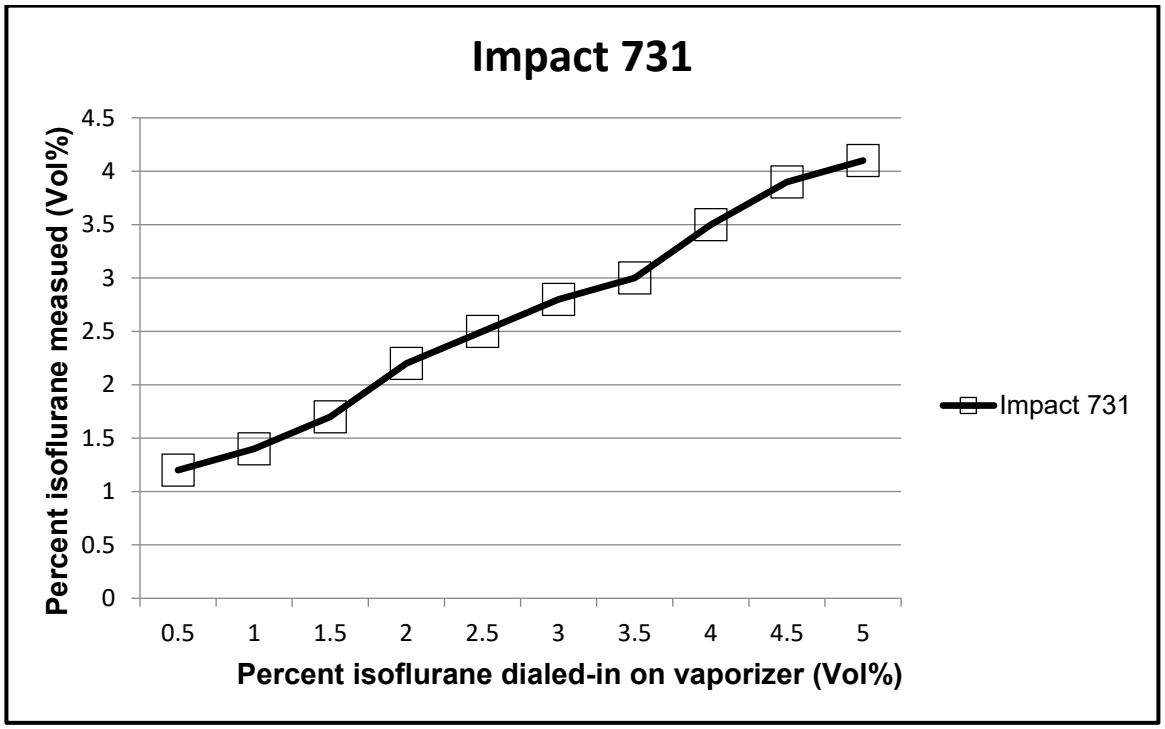
Comments: Any standard diameter respiratory tubing (22mm female connection) will fit onto the swivel adapter directly beneath the expiratory check valve. This scavenger tubing should be routed out of the OR area, and *not* attached to any direct suction source (maintain passive waste anesthetic gas scavenging). Recommend using wire mesh or the standard UPAC dust cap (Figure 1-7) to prevent debris or insects from entering and occluding waste anesthetic gas tubing.

D. Full setup

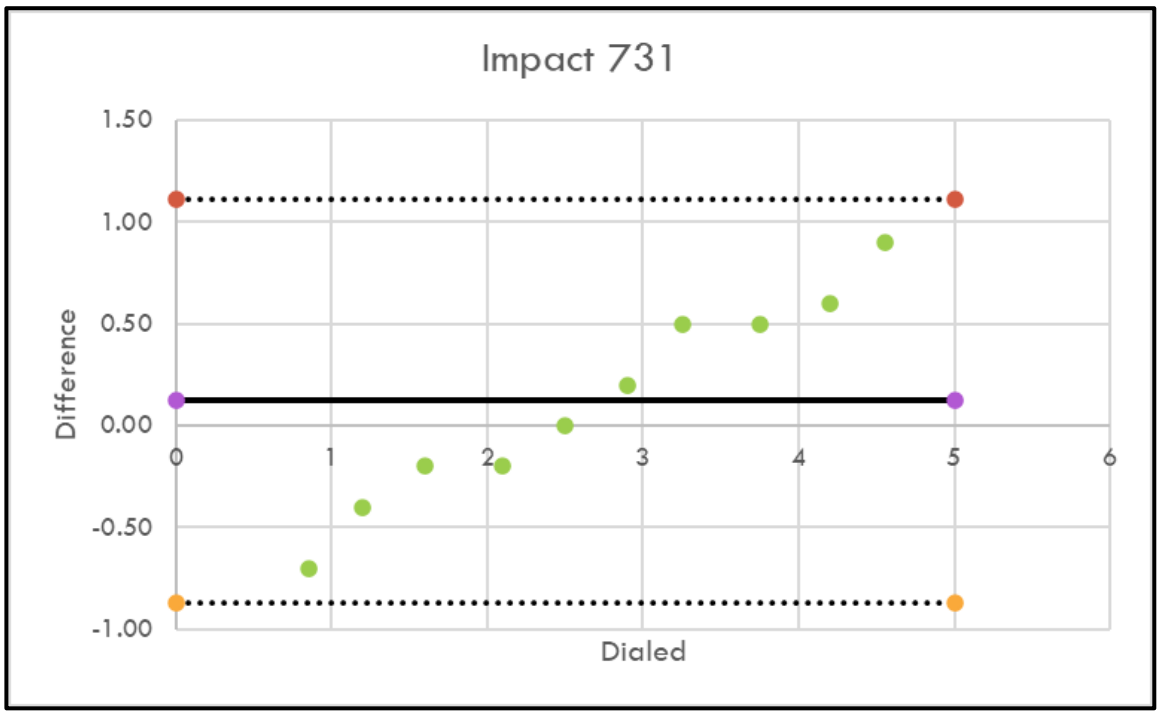
Figure 17. Complete setup of Impact 731 with UPAC. 1) Impact 731 circuit connected to UPAC outlet 2) Expiratory check valve 3) Pressure transducer

Comments: None

E. Expected UPAC vaporizer delivered agent concentrations (isoflurane shown)



F. Bland-Altman curve graph for isoflurane



G. Troubleshooting:

The standard circuits for the Impact 754 are completely compatible with the Impact 731.

V. HAMILTON T-1 Ventilator

A. Standard equipment

Figure 18. HAMILTON T-1 ventilator with standard patient circuit

Comments: Please refer to the HAMILTON T-1's operating instructions for pre-use checks and calibration.

B. Connection to UPAC

Figure 19. Side view of patient connections for HAMILTON T-1. 1) Outlet to UPAC 2) Inlet from patient

Comments: None

Figure 20. Expiratory valve diaphragm on ventilator circuit connection. 1) Expiratory valve diaphragm

Comments: The ventilator will not function if this valve is omitted before circuit assembly.

Figure 21. Side view of patient connections for HAMILTON T-1 with scavenger tubing. 1) HAMILTON T-1 outlet connection to UPAC via UPAC patient circuit tubing from the basic set 2) Input from patient expiratory limb of standard circuit 3) Expiratory check valve control connection (clear tubing) 4) Pressure transducer connection (blue tubing) 5) Scavenger tubing connected to expiratory check valve

Comments: The corrugated scavenger tubing is *not* included in the HAMILTON T-1 circuit. ***Respiratory tubing with a standard internal diameter of 22mm is needed to facilitate this portion of the setup.*** This scavenger tubing should be routed out of the OR area, and *not* attached to any direct suction source (maintain passive waste anesthetic gas scavenging). Recommend using wire mesh or the standard UPAC dust cap (Figure 1-7) to prevent debris or insects from entering and occluding waste anesthetic gas tubing.

Figure 22. Side view of patient connections for HAMILTON T-1 with expiratory tubing from HAMILTON T-1 standard breathing circuit to ventilatory expiratory check valve. 1) HAMILTON-T1 expiratory tubing

Comments: None

C. Waste anesthetic gas scavenger setup

Figure 23. Side view of scavenger tubing connection for HAMILTON T-1. 1) Scavenger tubing (Expiratory limb of HAMILTON T-1 standard breathing circuit omitted for emphasis on scavenger tubing connection.)

Comments: Due to the angle of the scavenger outflow, ***the right side of the HAMILTON T-1 ventilator should be elevated slightly to prevent kinking and occlusion of the scavenger corrugated tubing***. It is possible to attach one of the 90-degree elbows that are included with the HAMILTON T-1 set if the connection is wet with isopropyl alcohol in advance of assembly.

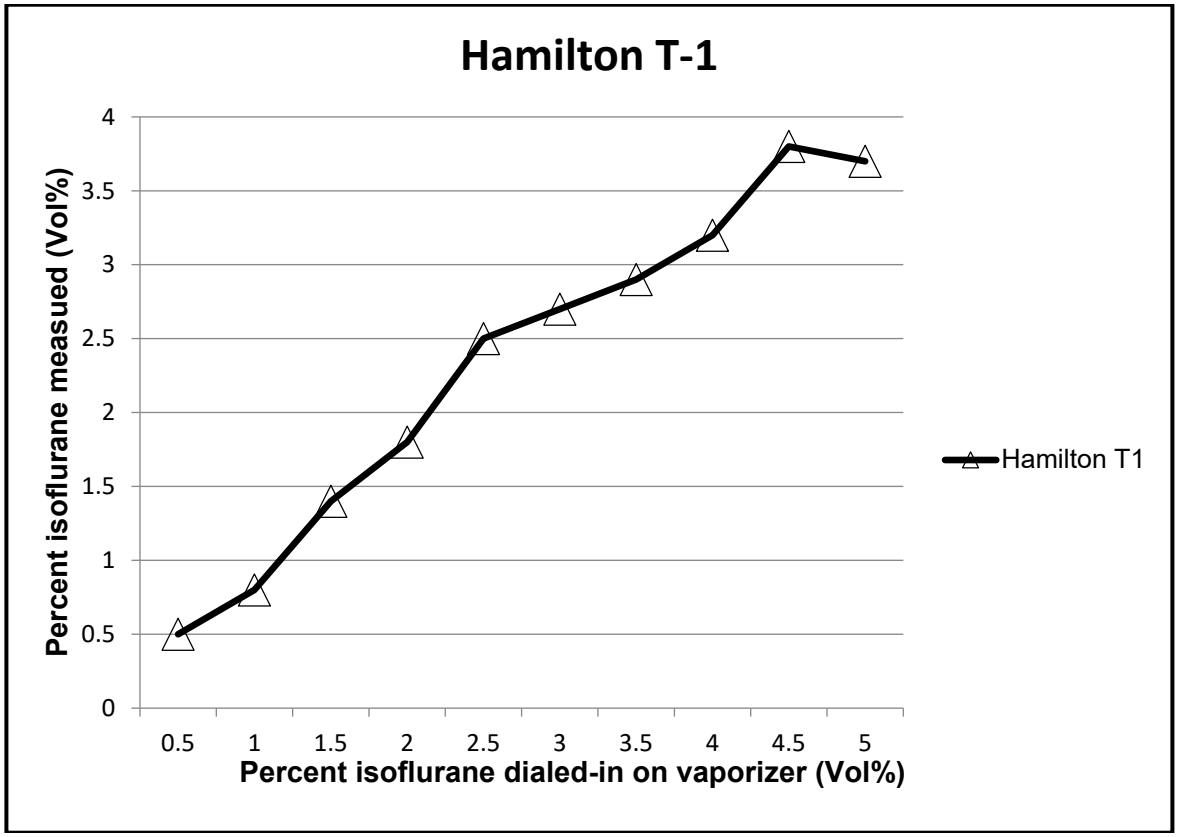
D. Full setup

Figure 24. Complete setup of HAMILTON T-1 with UPAC
Comments: None

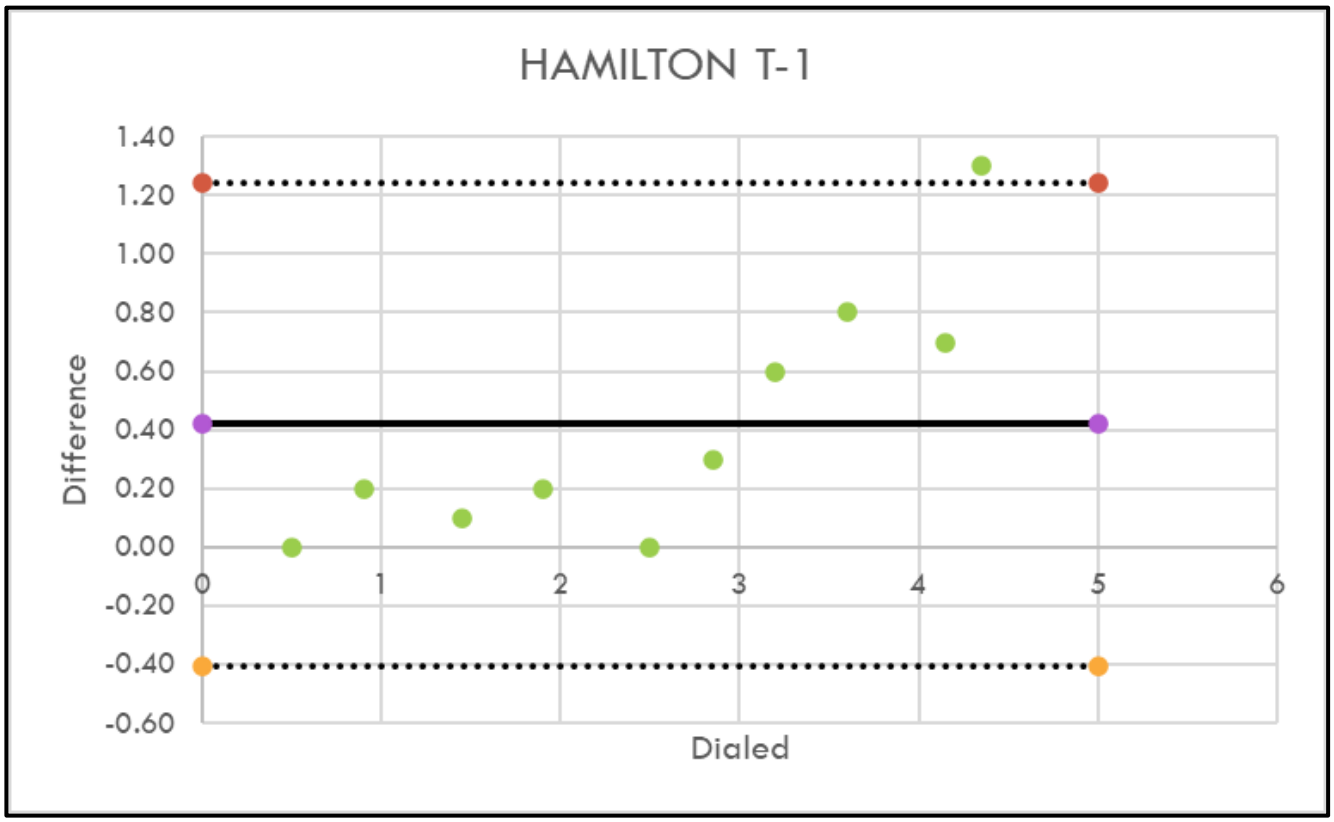
Figure 25. Side view of complete setup of HAMILTON T-1 with UPAC. 1) Bend and kinking of the scavenger tubing

Comments: Notice the bend and kinking of the scavenger tubing on the right side of the ventilator. ***The risk of scavenger and expiratory limb occlusion and barotrauma is relevant.***

E. Expected UPAC vaporizer delivered agent concentrations (isoflurane shown)



F. Bland-Altman curve graph for isoflurane



G. Troubleshooting:

Recommended best practice is to complete the pressure and flow sensor calibration sequence after complete assembly of the HAMILTON T-1 with the UPAC.

NOTE: Failure to complete these checks with the UPAC dial in the "off" position and the auxiliary oxygen inlet (Figure 3-1) on the UPAC occluded will result in a failed check error message on the HAMILTON T-1 screen.

VI.SAVe II Ventilator

A. Required equipment

Figure 26. Basic set and SAVe II ventilator. 1) UPAC corrugated tubing and scavenger tubing 2) SAVe II ventilator 3) Power cord 4) Standard circuit patient connection 5) Corrugated extension at patient connection

Comments: The scavenger tubing is not a standard tubing to the SAVe II.
***Long-term use of the SAVe II should be avoided in critical patients. It should only be used when other ventilators are not available.*

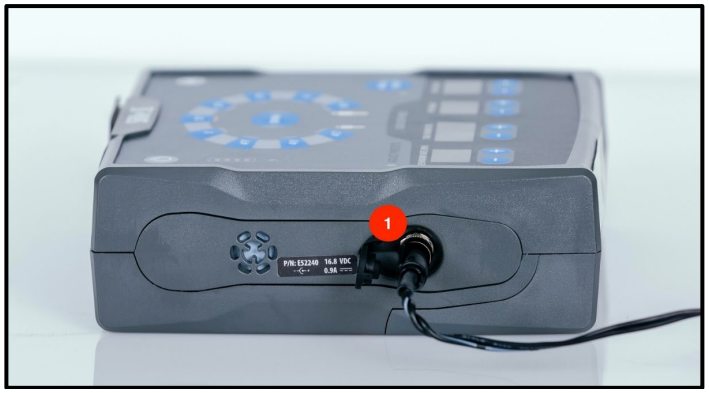


Figure 27 SAVe II ventilator power. 1) Power connection

Comments: None

Figure 28. SAVe II ventilator with standard patient circuit attached

Comments: The standard circuit from the Impact 754/731 has antectodal reports of compatability with the SAVe II.

Figure 29. Top view of patient connections for SAVe II. 1) Outlet connection to UPAC via UPAC patient circuit tubing from the basic set 2) Pressure transducer tubing (blue) 3) Expiratory check valve tubing (clear)

Comments: None

B. Connection to UPAC

Figure 30. SAVe II with UPAC connected

Comments: Note that scavenger tubing is not connected.

C. Waste anesthetic gas scavenger setup

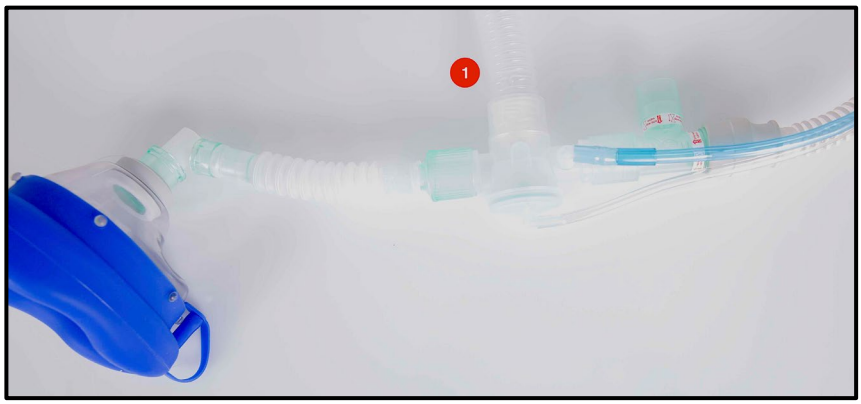


Figure 31. SAVe II standard circuit with corrugated tubing for scavenging connected. 1) Corrugated tubing for scavenging

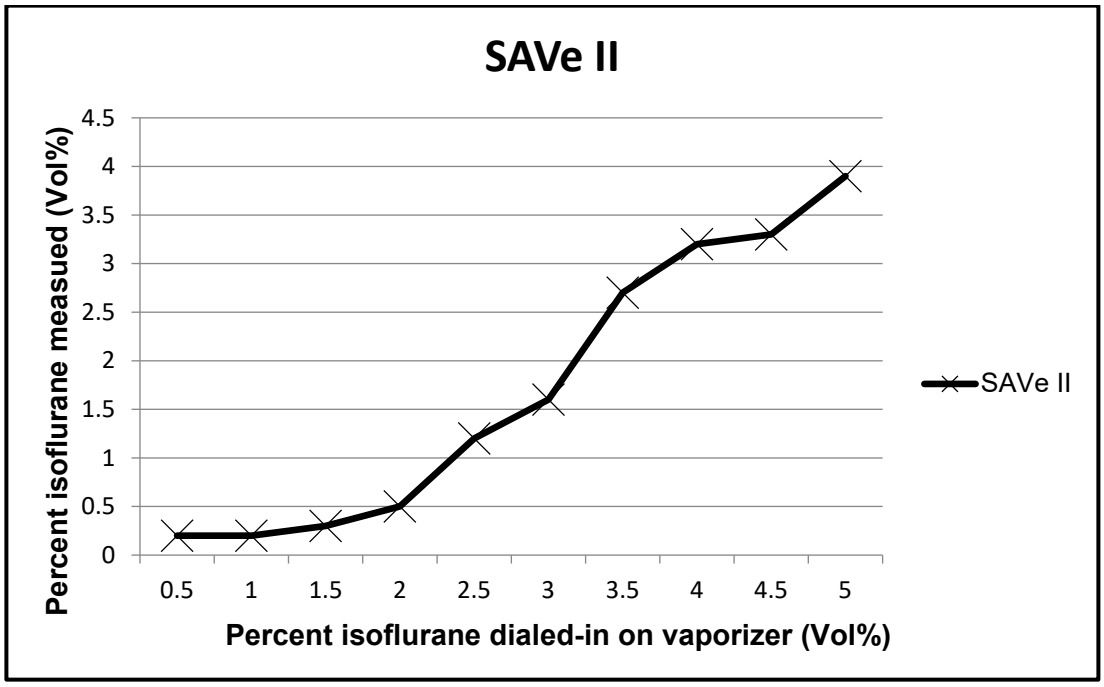
Comments: ***The outer diameter of the tubing must be increased by wrapping one-inch silk tape around one end in order for it to seat beneath the expiratory check valve of the SAVe II circuit.*** This scavenger tubing should be routed out of the OR area, and *not* attached to any direct suction source (maintain passive waste anesthetic gas scavenging). Recommend using wire mesh or the standard UPAC dust cap (Figure 1-7) to prevent debris or insects from entering and occluding waste anesthetic gas tubing.

D. Full setup

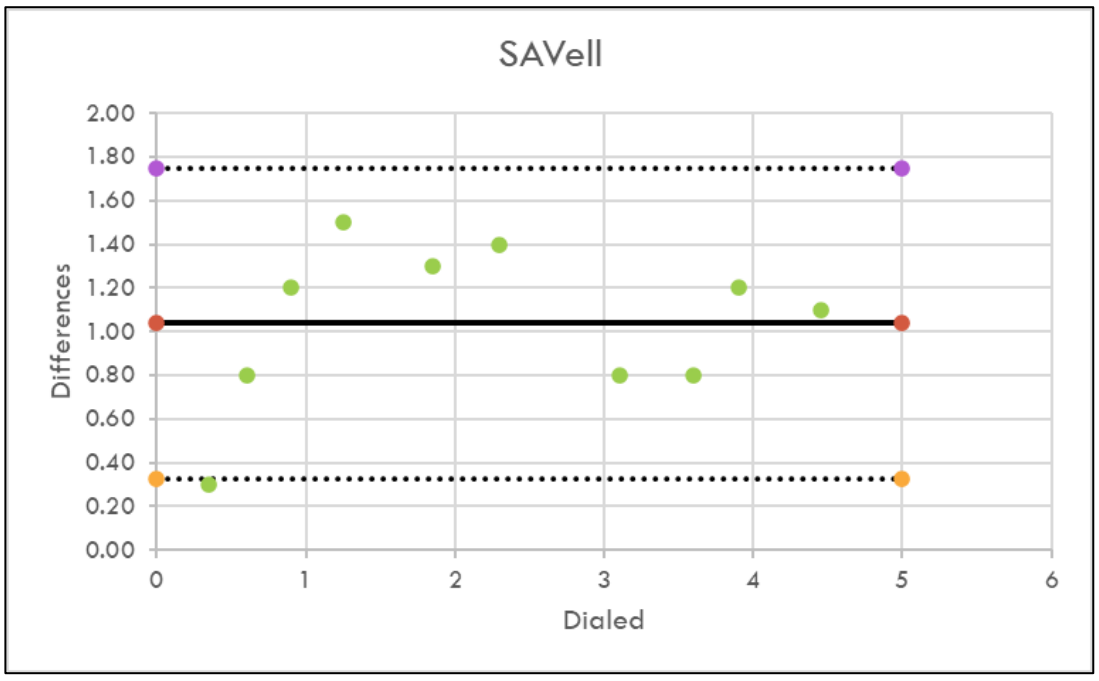
Figure 32. Complete setup of SAVe II with UPAC and scavenger tubing attached. 1) Scavenger tubing

Comments: The outer diameter of the tubing must be increased by wrapping one-inch silk tape around one end in order for it to seat beneath the expiratory check valve of the SAVe II circuit.

E. Expected UPAC vaporizer delivered agent concentrations (isoflurane shown)



F. Bland-Altman curve graph for isoflurane



G. Troubleshooting:

The noise from the compression chamber increases dramatically as tidal volumes and rates increase. Noise discipline as well as normal verbal communication will likely be compromised in these situations.

Appendix: Frequently Asked Questions about Managing Mechanical Ventilation and Using the UPAC Vaporizer in Deployed Settings

Purpose

This addendum serves to address frequently asked questions (FAQs) the authors received from anesthesia providers practicing in deployed settings.

FAQs

Q: Is the UPAC and mechanical ventilation setup meant for use during induction of a non-intubated patient?

A: No. The setup outlined in this CPG cannot serve as a substitute anesthesia machine and is meant for use post-intubation. If the provider wishes to use the UPAC during induction, they must use a self-inflating bag to provide manual ventilation to the patient and confirm endotracheal intubation. The provider must also emerge the patient using a self-inflating bag or by setting the ventilator on "spontaneous" (if available) and emerging with the UPAC in the "Off" dial position.

Q: Does the CPG address the use of the UPAC vaporizer in a pull-through configuration?

A: No, the current version of the CPG represents the use of the UPAC in a push-through configuration, meaning the ventilator pushes air and oxygen over the volatile agent in the UPAC for delivery to the patient.

Q: Why is the use of the UPAC in a pull-through configuration not discussed in this CPG?

A: While the Impact 731 and 754 have been used by multiple anesthesia providers in the pull-through configuration in deployed and training environments successfully, the effect of introducing anesthetic vapor into the impeller-driven compression chamber of the Hamilton T1 is unknown. Based on communication with the engineering branch at Hamilton Medical, using the T1 and UPAC in this configuration would be considered "off label use" by the manufacturer. Bench research studies are currently being designed to address this knowledge deficit, and will be relayed in a future addendum.

Q: Are there deployed transport ventilators that will preclude using the UPAC in a pull-through configuration?

A: Yes. The civilian version of the Hamilton T1, which has been furnished to deploying surgical teams lacks the air inlet fitting on the back of the ventilator (where an NBC filter could also be attached). Instead, there is simply a rectangular cutout to allow for air entry into the compression chamber of the T1 (see image below).

HAMILTON-T1 transport ventilator | Hamilton Medical (hamilton-medical.com)

This difference eliminates the 22mm fitting required to connect the UPAC patient outlet to the air inlet on the T1, as seen in the image below.

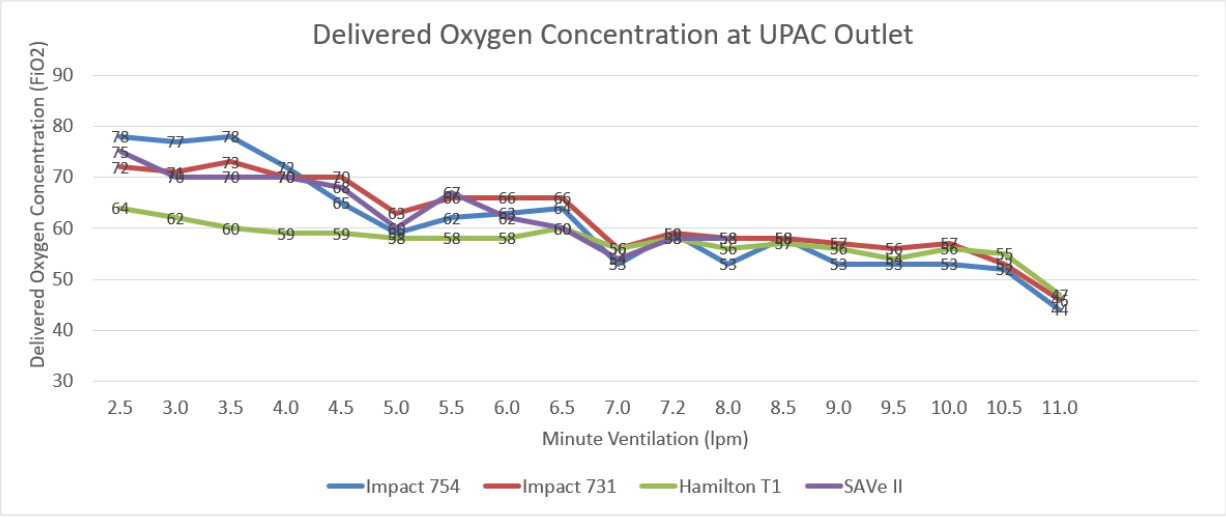
22mm NBC Filter Adapter. Author provided image.

Q: In what ways can supplemental oxygen be added to the delivered gases?

A: Low pressure oxygen, as delivered from a deployable oxygen concentrator, can be added via the supplemental oxygen inlet fitting on the side of the UPAC (see Figure 3 (1) in the above CPG) or the yellow oxygen inlet fitting on the circuit attachment side of the Hamilton T1. High pressure oxygen from a cylinder with a regulator can be attached via the diameter index safety system (DISS) fitting on the ventilators discussed in the CPG (except for the SAVeII).

Q: What are the FiO2 and flow limitations?

A: If the oxygen concentrator being used in a deployed setting has a maximum flow rate of 5 liters per minute, the delivered FiO2 will vary from a high of 0.78 FiO2 (78%) at a minute ventilation of 2.5 liters per minute to a low of 0.44 FiO2 (44%). These values are based on a recent bench research study's unpublished secondary analysis data. If higher flow rates are possible, these values will increase as well.



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