UNIVERSAL PORTABLE ANESTHESIA COMPLETE (UPAC) VAPORIZER AND MECHANICAL VENTILATION

Feb 2025

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Photos courtesy of Medical Photography, San Antonio Military Medical Center, Ft. Sam Houston, TX; and Tripler Army Medical Center, HI

I. Summary of Changes

A. Updated language to emphasize significant risk of barotrauma while using Universal Portable Anesthesia Complete (UPAC) with HAMILTON T-1 ventilator in the pull-through configuration while utilizing high-pressure oxygen (45-55 psi via high pressure connection on HAMILTON T-1) and to strongly discourage its use in this manner.

B. Updated photos and added step-by-step guide for proper setup of the UPAC with the HAMILTON T-1 in the push-through configuration, which has recently been fielded as a safe, effective anesthesia delivery platform in the deployed environment.

C. Rearranged content to reflect availability of UPAC-compatible ventilator equipment currently fielded by the United States Army.

D. Removed the photos and step-by-step guide for proper setup of the Impact 754 Ventilator. This ventilator is no longer being fielded by U.S. Army FORSCOM units.

E. Discussed in greater detail the practical nuances of deployed anesthesia using UPAC with currently fielded ventilators (e.g. preoxygenation, induction, emergence).

F. Discussed the difference between the Datex-Ohmeda and the new G.A.S. Drawover and some of the nuances and volatile agent calibration differences between the vaporizers.

G. Replaced terminology such as “Forward Resuscitative Surgical Teams” to “Forward Resuscitative Surgical Detachments” in accordance with updated U.S. Army doctrine.

H. Included photos and guidance for manual setup in its native configuration using assisted ventilation with the self-inflating bag, non-rebreathing valve, and scavenger adaptor with corrugated tubing for the exhaled gases.

I. Addressed the use of side-stream, mainstream, or EMMA End-tidal carbon dioxide **(**EtCO2) monitoring when using Drawover setup.

J. Addressed the use of an oxygen concentrator vs. oxygen cylinder in a resource limited environment or during Large-Scale Combat Operations (LSCO).

K. Added supporting references.

II. Introduction

A. *This Clinical Practice Guideline (CPG) provides a clear, step-by-step guide for properly setting up the UPAC with each of the fielded ventilators and in the manual configuration using assisted ventilation with the self-inflating bag. It ensures anesthesia providers across all services can deliver safe and effective anesthesia to our warfighters.*

B. The capability to deliver low-resistance portable inhalational anesthesia without any electrical power, whether with or without a portable ventilator or a compressed oxygen source, is a fundamental requirement for Forward Surgical Teams operating in austere and resource-constrained environments. The UPAC Drawover is currently the only alternative available for military anesthesia providers in remote locations to fulfill these specifications. This CPG will emphasize the importance of having a good working knowledge of the UPAC Drawover and its versatility by using a portable ventilator as a force multiplier to provide mechanical ventilation while delivering a volatile agent.[1, 2, 8, 9]

C. Anesthesia providers in Forward Resuscitative Surgical Detachments (FRSDs) or ad hoc surgical teams may have limited or no experience with the UPAC as a delivery system for general anesthesia. As the U.S. military has modernized, new methods of mechanical ventilation have been fielded to support forward-deployed anesthesia providers. These ventilators include the HAMILTON-T1, Impact Uni-Vent 731 (Impact 731), and the SAVeII. The HAMILTON-T1 and Impact 731 are the most readily available to the FRSDs. While the SAVeII is available to some FRSDs, it is not recommended for long-term use and should only be used when other ventilators are not available.[1-5]

D. This CPG exclusively describes the utilization of the UPAC vaporizer in the push-through configuration when using current ventilators. Although there has been historical utilization of the UPAC Drawover in the pull-through configuration with the Impact 754 and 731 ventilators, the utilization of the HAMILTON-T1 in this configuration, while employing high-pressure oxygen (45-55 psi), is not recommended. This specific setup with the HAMILTON-T1 carries a substantial risk of causing barotrauma, rendering it highly undesirable and strongly discouraged.

E. This CPG will describe the UPAC Drawover in a manual configuration using the self-inflating bag, non-rebreathing valve, and scavenger adaptor (G.A.S.) with corrugated tubing for the exhaled gases. This setup gives the anesthesia provider the ability to perform a general anesthetic with a volatile agent without any need for power.[1, 2]

F. The CPG will address the practical challenges of using the UPAC Drawover with currently fielded ventilators as it pertains to preoxygenation and emergence and include current recommendations.

III. UPAC Drawover 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 ("long tubing"), oxygen tubing, and facemask are known as the basic set. 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 or Jackson Rees circuit) 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) Stand.

Comments: UPAC vaporizer details. The ventilator is connected to the vaporizer inlet (Figure 4-1) with either the patient curcuit tubing ("long tubing" or the short tubing segment). The standard ventilators' patient circuits are attached to the vaporizer outlet (Figure 4-3). It is recommended to secure the vaporizer stand to the work surface area due to the top-heavy nature of the vaporizer.

B. Drawover: Datex-Ohmeda, Inc

Comments: The Datex-Ohmeda vaporizers are not calibrated for Sevoflurane but instead Isoflurane, Halothane, and with the generic disc and corresponding table located on the side of the Drawover (Isoflurane, Halothane, Enflurane, and Diethyl Ether). The Datex-Ohmeda vaporizers have been replaced by a newer Drawover from G.A.S..[1]

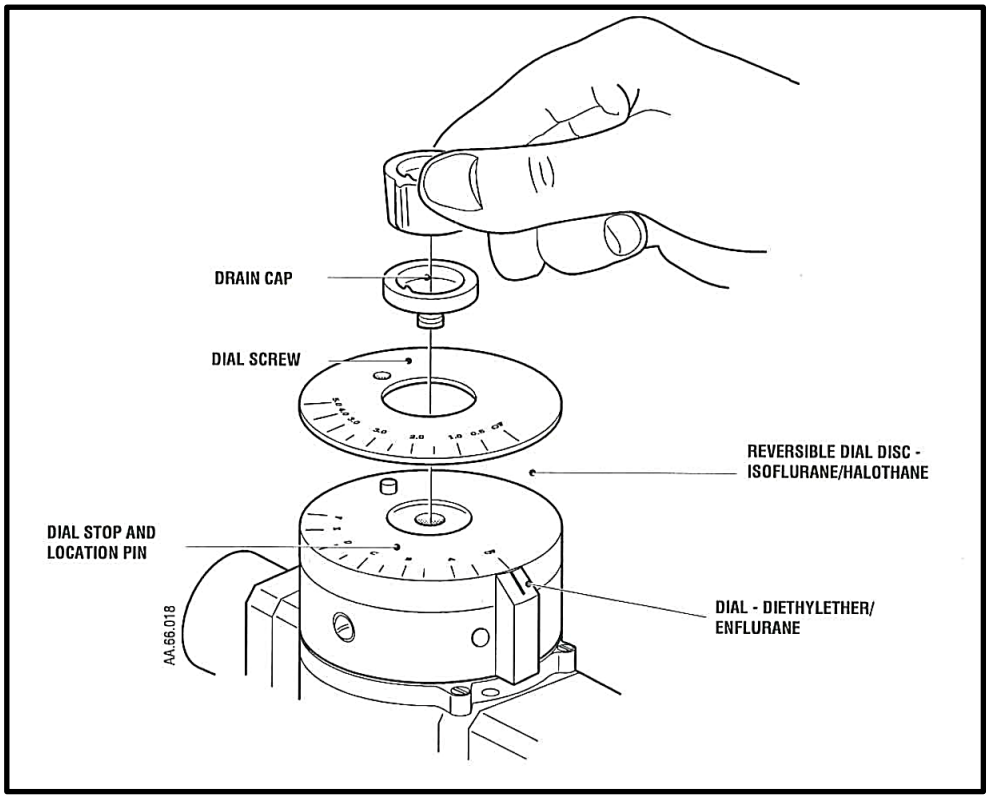


Figure 5. Datex-Ohmeda UPAC vaporizer interchangeable dial disc. Adapted from: Datex-Ohmeda, Inc. Universal PAC Operation and Maintenance Manual (#1101-0001-000), Aug 1997.[1]

Drug Type / Dial Setting	Nominal Calibrations			
	% v/v Diethylether	% v/v Enflurane	% v/v Halothane	% v/v Isoflurane
A	1.55	0.50	0.50	0.60
B	2.70	0.90	1.00	1.20
C	4.80	1.70	2.00	2.15
D	6.65	2.40	3.00	3.10
E	8.20	3.10	4.00	4.00
F	10.10	3.85	5.00	5.00

Figure 6. Datex-Ohmeda UPAC vaporizer corresponding table located on side of Drawover (Isoflurane, Halothane, Enflurane, and Diethyl Ether). Adapted from: Datex-Ohmeda, Inc. Universal PAC Operation and Maintenance Manual (#1101-0001-000), Aug 1997.[1]

C. Drawover: G.A.S.

Comments: G.A.S. is currently producing the new Anesthesia Drawover Vaporizer specifically calibrated for Isoflurane and Sevoflurane. The Drawover comes with a reversible disc and generic dial and corresponding table located on the side of the Drawover (Isoflurane and Sevoflurane).[2]

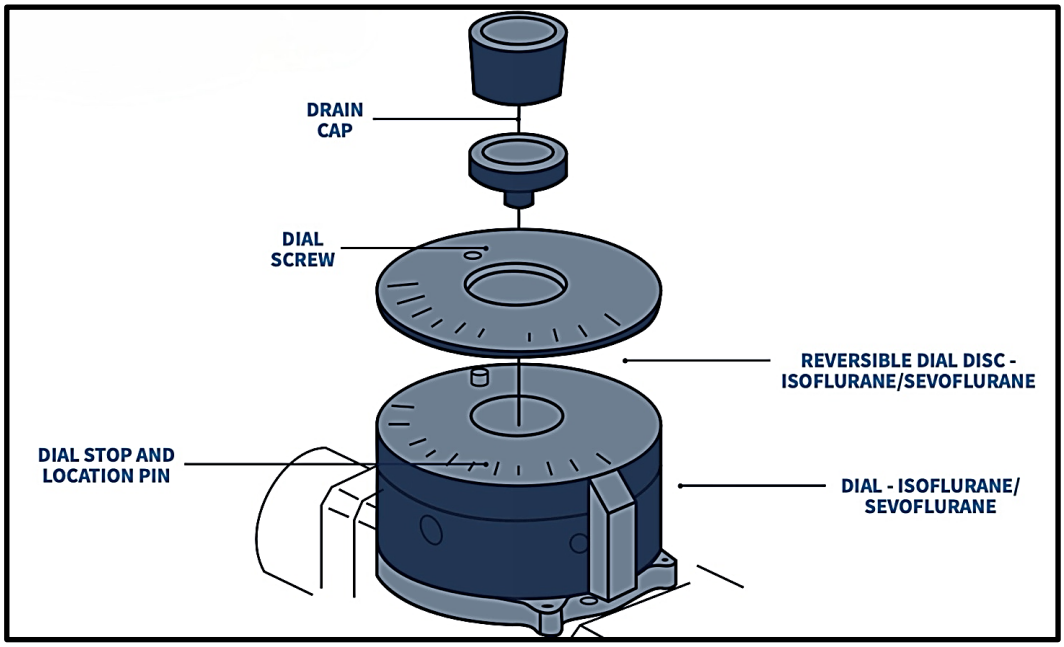


Figure 7. G.A.S. vaporizer interchangeable dial disc. Adapted from: G.A.S., Inc. Drawover Vaporizer Operation and Maintenance Manual (REV 2), Oct 2022.[2]

Drug Type | Dial Setting	Nominal Calibrations	
	% v/v Isoflurane	% v/v Sevoflurane
A	0.60	0.35
B	1.20	0.80
C	2.15	1.60
D	3.10	2.30
E	4.00	3.00
F	5.00	3.70

Figure 8. G.A.S. corresponding table located on side of Drawover (Isoflurane and Sevoflurane). Adapted from: G.A.S., Inc. Drawover Vaporizer Operation and Maintenance Manual (REV 2), Oct 2022.[2]

IV. HAMILTON-T1

A. Equipment

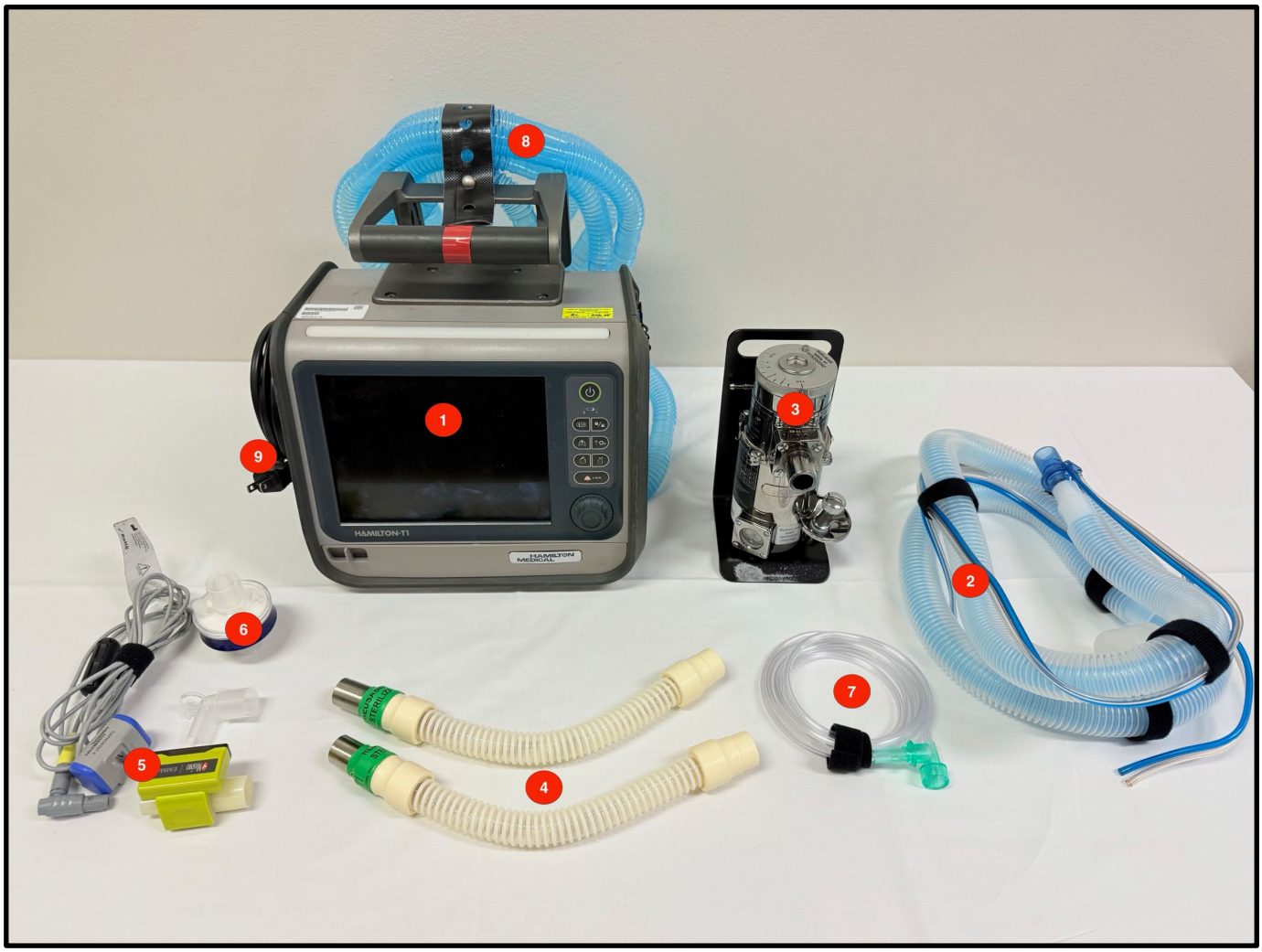


Figure 9. HAMILTON T-1 ventilator and recommended material for setup with UPAC. 1) HAMILTON-T1 ventilator 2) Standard HAMILTON patient circuit with Expiratory Valve 3) UPAC Drawover 4) Short tubing segments 5) HAMILTON-T1 CAPNOSTAT-5 mainstream or EMMA EtCO2 sensor 6) Heat and Moisture Exchanger (HME) (Filter 7) O2 tubing 8) Scavenger circuit 9) Power cord.

Comments: Please refer to the HAMILTON-T1 operating instructions for pre-use checks and calibration. Standard HAMILTON-T1 manufacturer issuance includes CAPNOSTAT-5 CO2 cable. This requires the mainstream adapter. However, if the provider has access to separate gas analysis capabilities, sidestream sampling, or EMMA capnograph, they may be arranged before the elbow adapter or heat-moisture exchange.[3]

B. Connection to UPAC



Figure 10. Side view of patient connection for HAMILTON-T1. 1) Outlet to UPAC (inspiratory limb) 2) Inlet from patient (expiratory limb) 3) Connected scavenger tubing 4) Flow sensor connectors 5) Pneumatic nebulizer port 6) Input for CAPNOSTAT-5 cord.

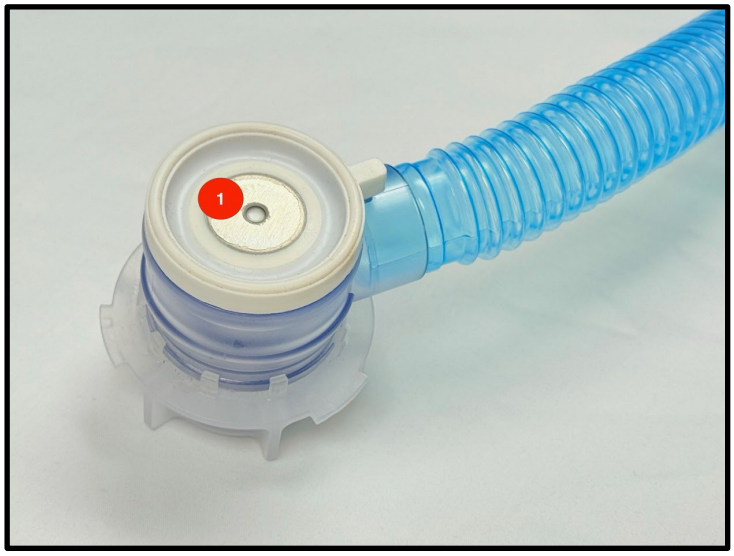


Figure 11. 1) Expiratory valve set.

Comments: The expiratory valve set is complete with a detachable valve diaphragm. The HAMILTON T-1 will not function without the valve diaphragm properly installed. It is important to verify the expiratory

valve is included with the patient curcuit. Depending upon the NSN number used, the patient curcuit and expiratory valve might have to be ordered separately.

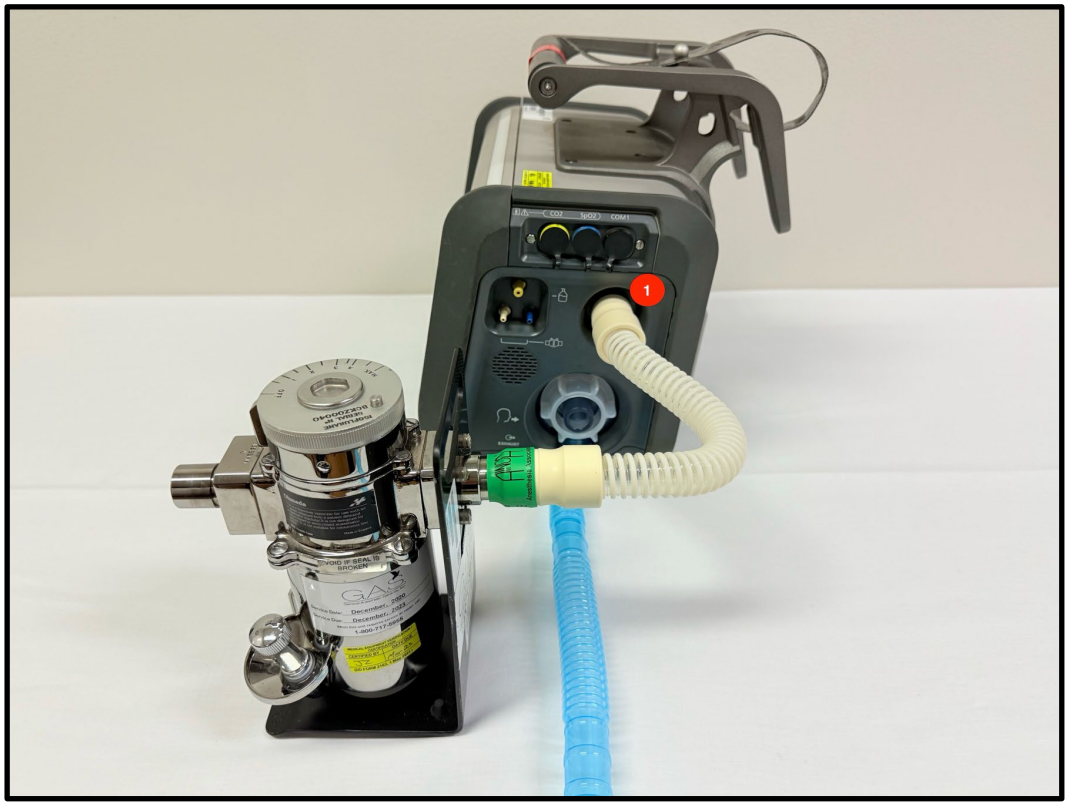


Figure 12. 1) HAMILTON-T1 inspiratory limb to UPAC via short tubing segment.

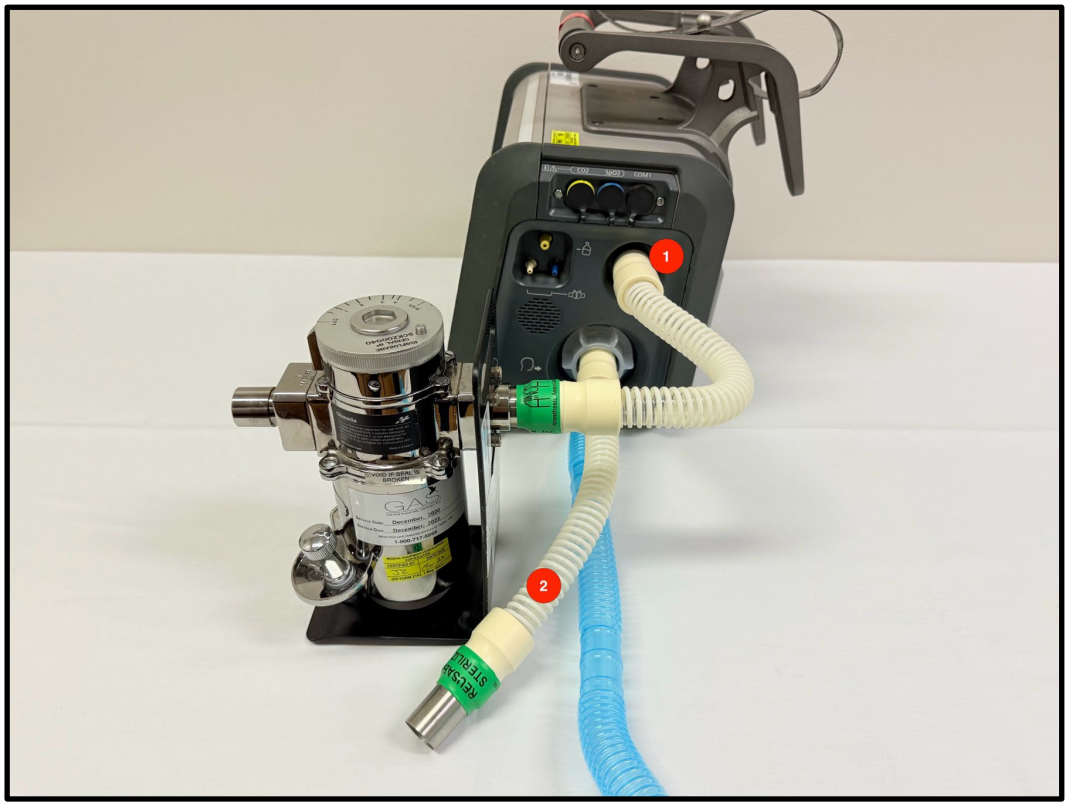


Figure 13. 1) HAMILTON-T1 inspiratory limb to UPAC 2) Expiratory limb.

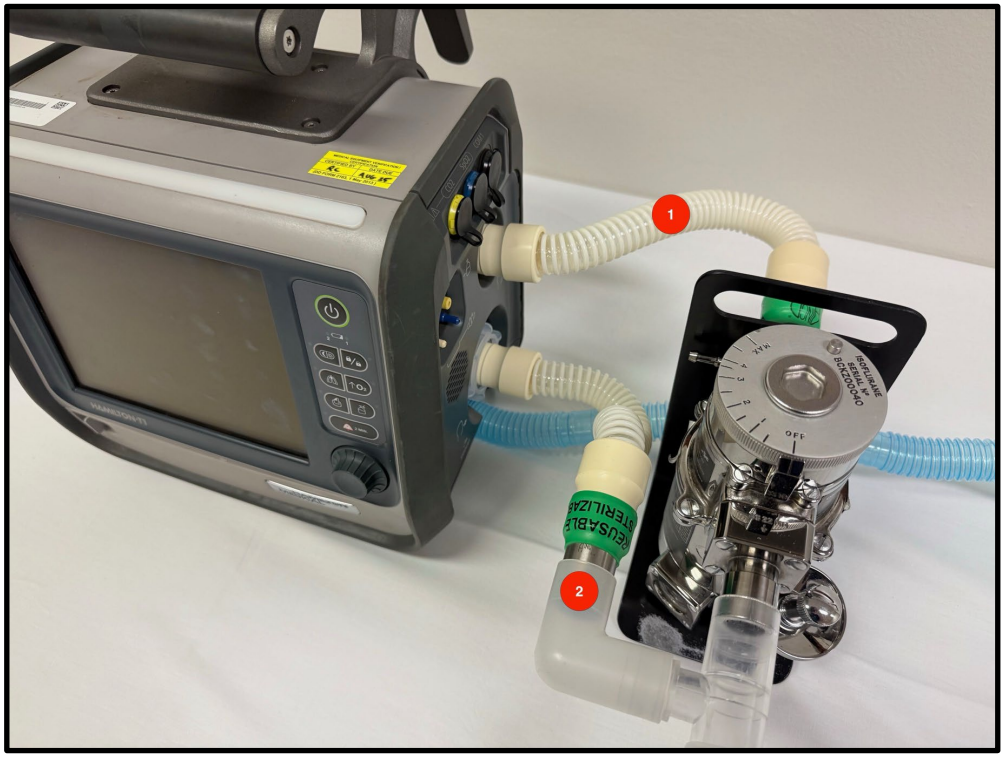


Figure 14. 1) HAMILTON-T1 inspiratory limb 2) Expiratory limb from patient circuit.

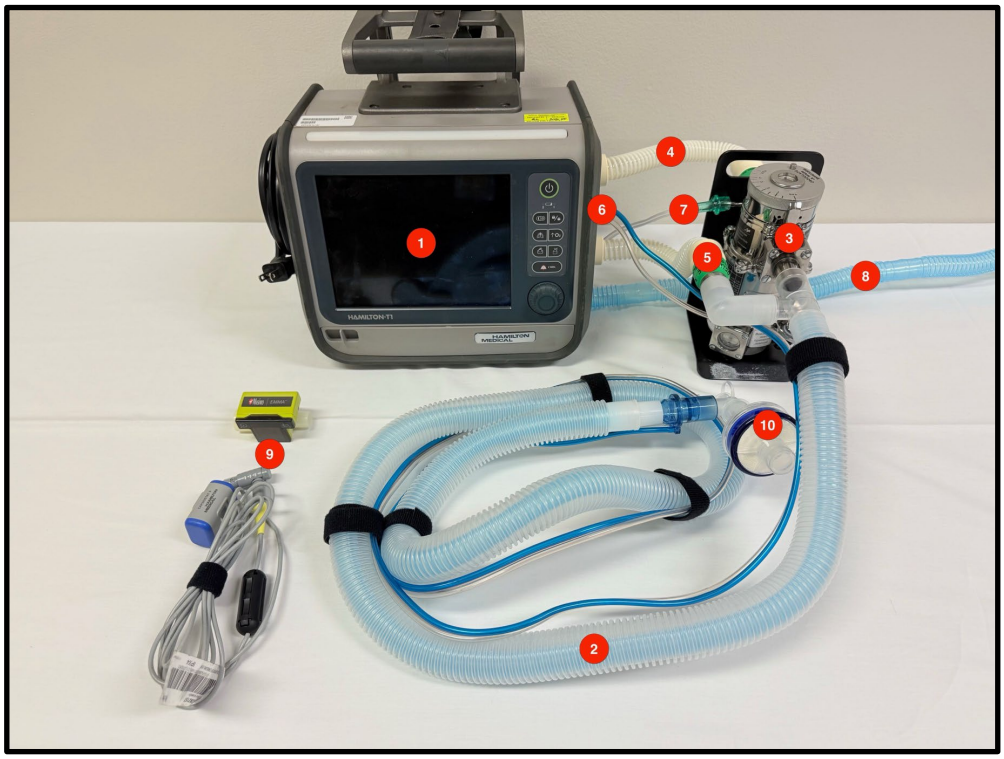


Figure 15. Complete setup. 1) HAMILTON-T1 ventilator 2) Standard HAMILTON patient curcuit 3) UPAC Drawover 4) Inspiratory segment 5) Expiratory segment 6) Flow sensor connectors 7) O2 tubing 8) Scavenger circuit 9) CAPNOSTAT-5 mainstream or EMMA EtCO2 sensor 10) HME Filter.

C. Waste Anesthetic Gas Scavenger Setup

It is helpful to remove the expiratory valve set from T-1 to appropriately attach the scavenger tubing. To prevent obstruction of the scavenger tubing, the HAMILTON T-1 should be elevated, or a right angle adaptor can be used. Obstruction of the scavenger tubing will limit expiratory flow and may manifest as high PEEP and inspiratory pressure.

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.

D. Expected UPAC Vaporizer Delivered Agent Concentrations (Isoflurane)

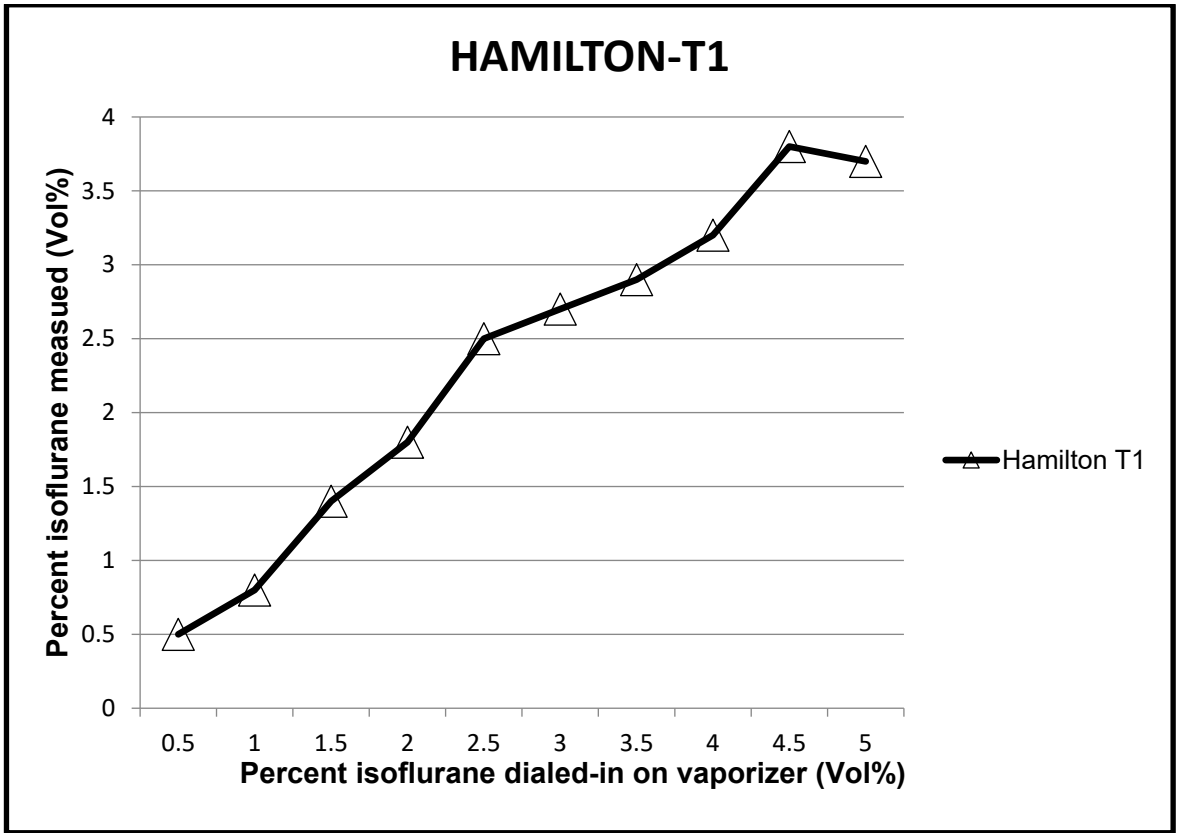


Figure 16. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

E. Bland-Altman Curve Graph for Isoflurane

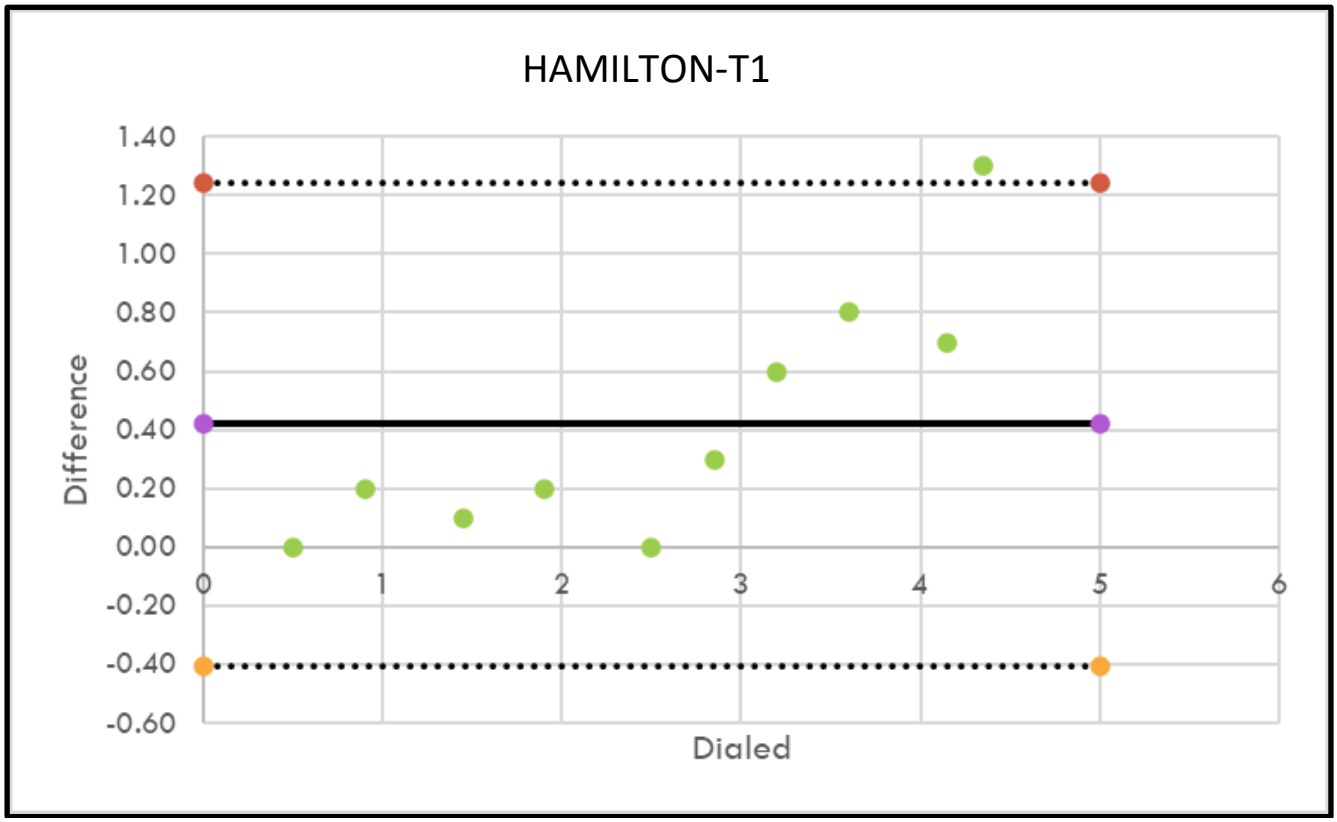


Figure 17. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

F. Troubleshooting

Recommended best practice is to complete the leak test and flow sensor calibration after complete assembly of the HAMILTON-T1 with the UPAC. The UPAC oxygen inlet will need to be occluded to successfully pass these tests.

V. Impact 731 Ventilator

A. Required Equipment

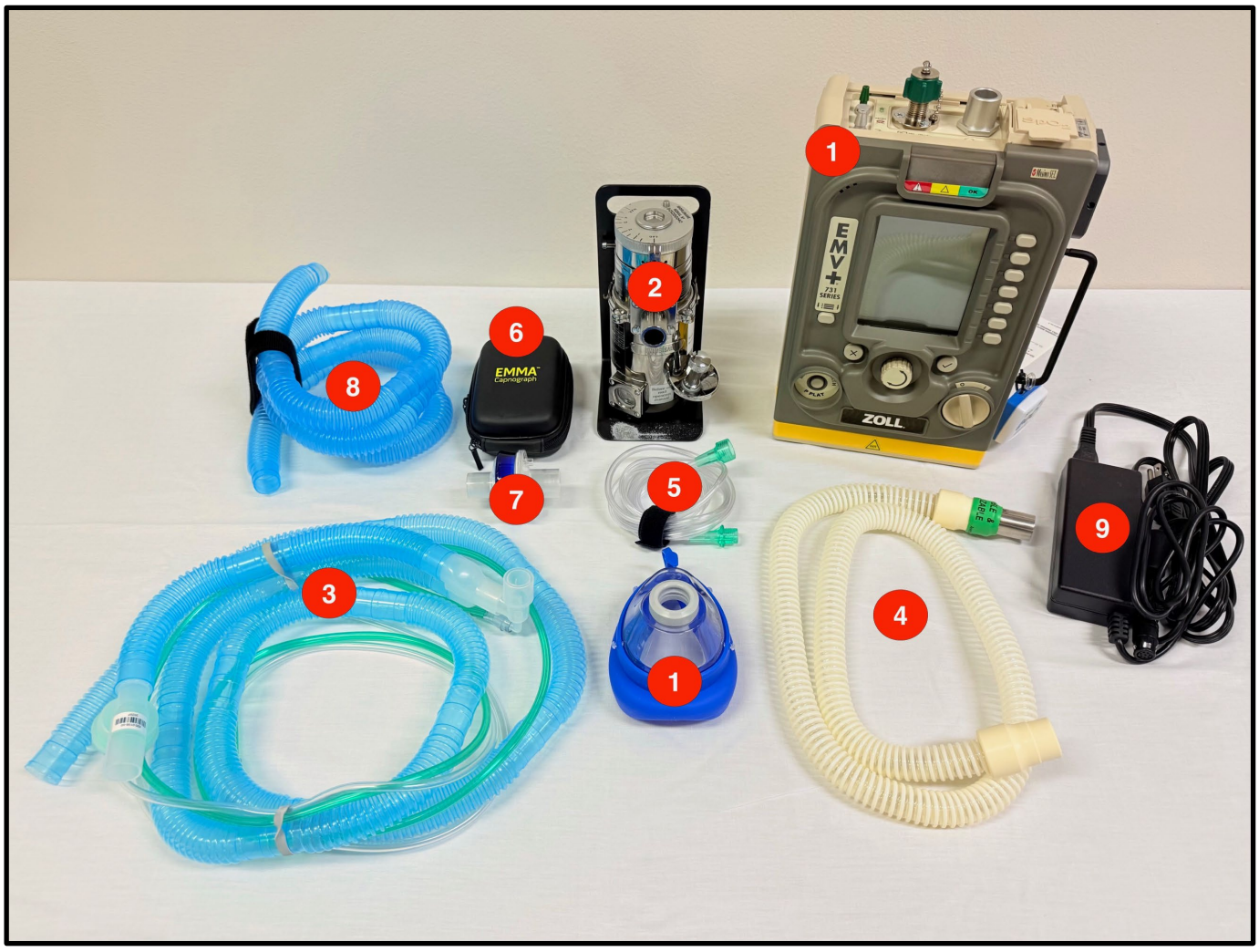


Figure 18. Impact 731 ventilator and recommended material for setup with UPAC. 1) Impact 731 ventilator 2) UPAC drawover 3) Standard Impact patient circuit 4) UPAC patient circuit tubing from the basic set 5) O2 tubing 6) EMMA capnograph 7) HME filter 8) Scavenger tubing 9) Power Cord.

Comments: None



Figure 19. 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.

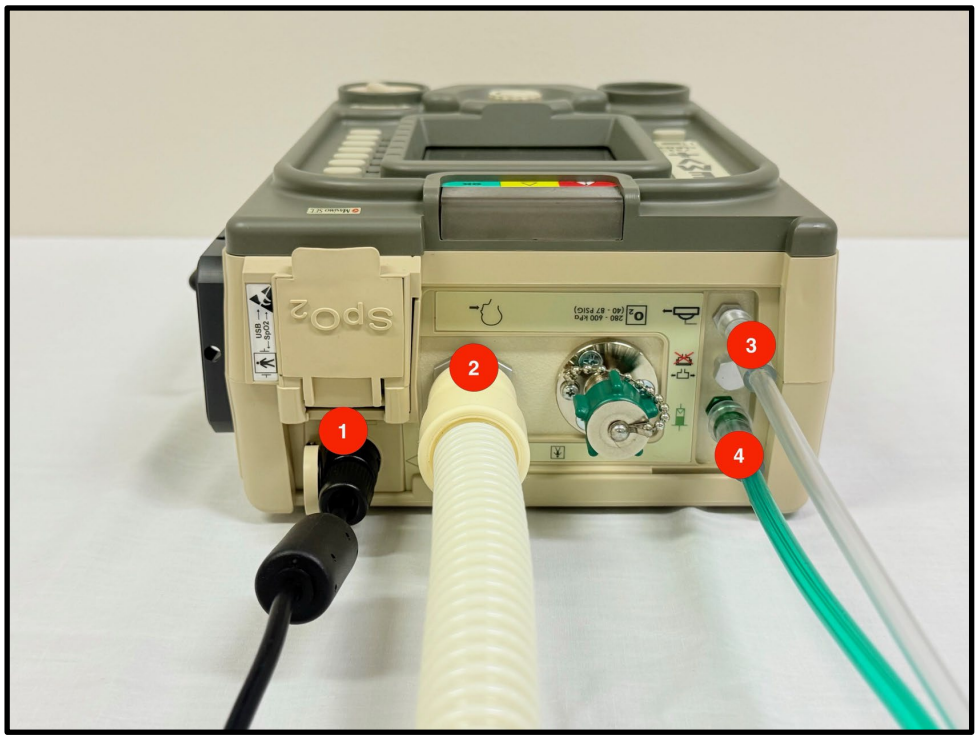


Figure 20. Top view of patient connections for Impact 731. 1) Power cord connected 2) Outlet connection to vaporizer via UPAC patient circuit tubing from the basic set 3) Expiratory check valve tubing connected (clear tubing) 4) Pressure transducer tubing connected (green tubing).

Comments: As with the Impact 754, the pressure transducer tubing (green) 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 occluded during use.

B. Connection to UPAC

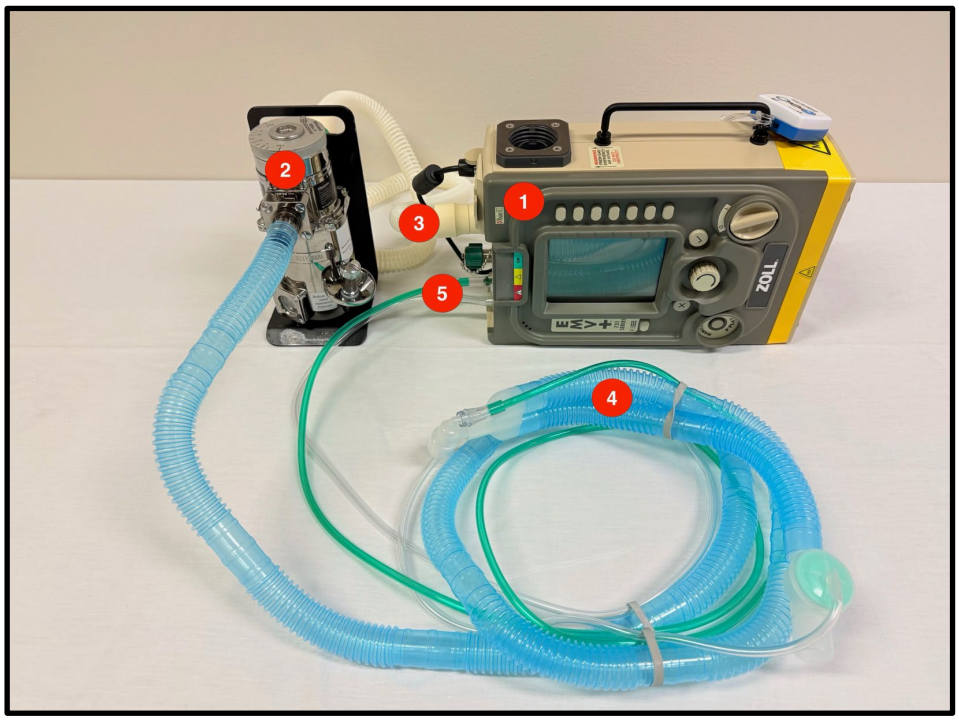


Figure 21. 1) Impact 731 ventilator 2) UPAC drawover 3) UPAC patient circuit tubing 4) Standard Impact patient circuit 5) Expiratory check valve and Pressure transducer tubing.

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

C. Waste Anesthetic Gas Scavenger Setup

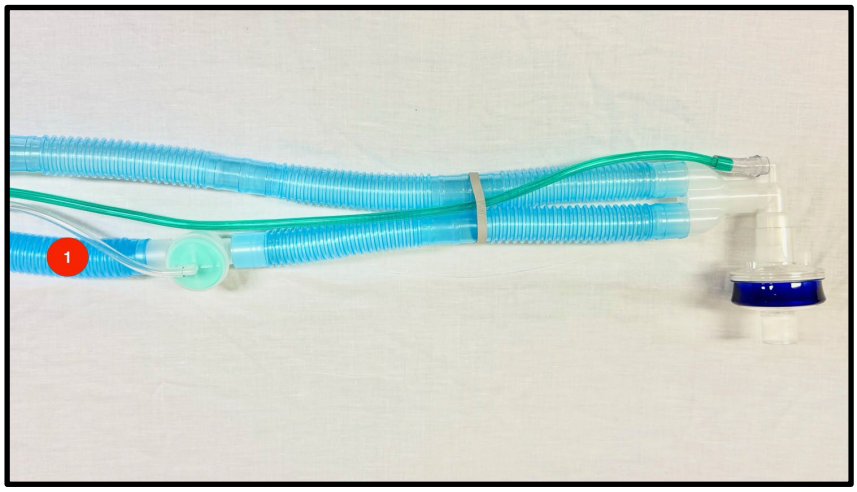


Figure 22. Waste anesthetic gas tubing connection to expiratory check valve of standard Impact 731 circuit. 1) Waste anesthetic gas tubing connection.

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

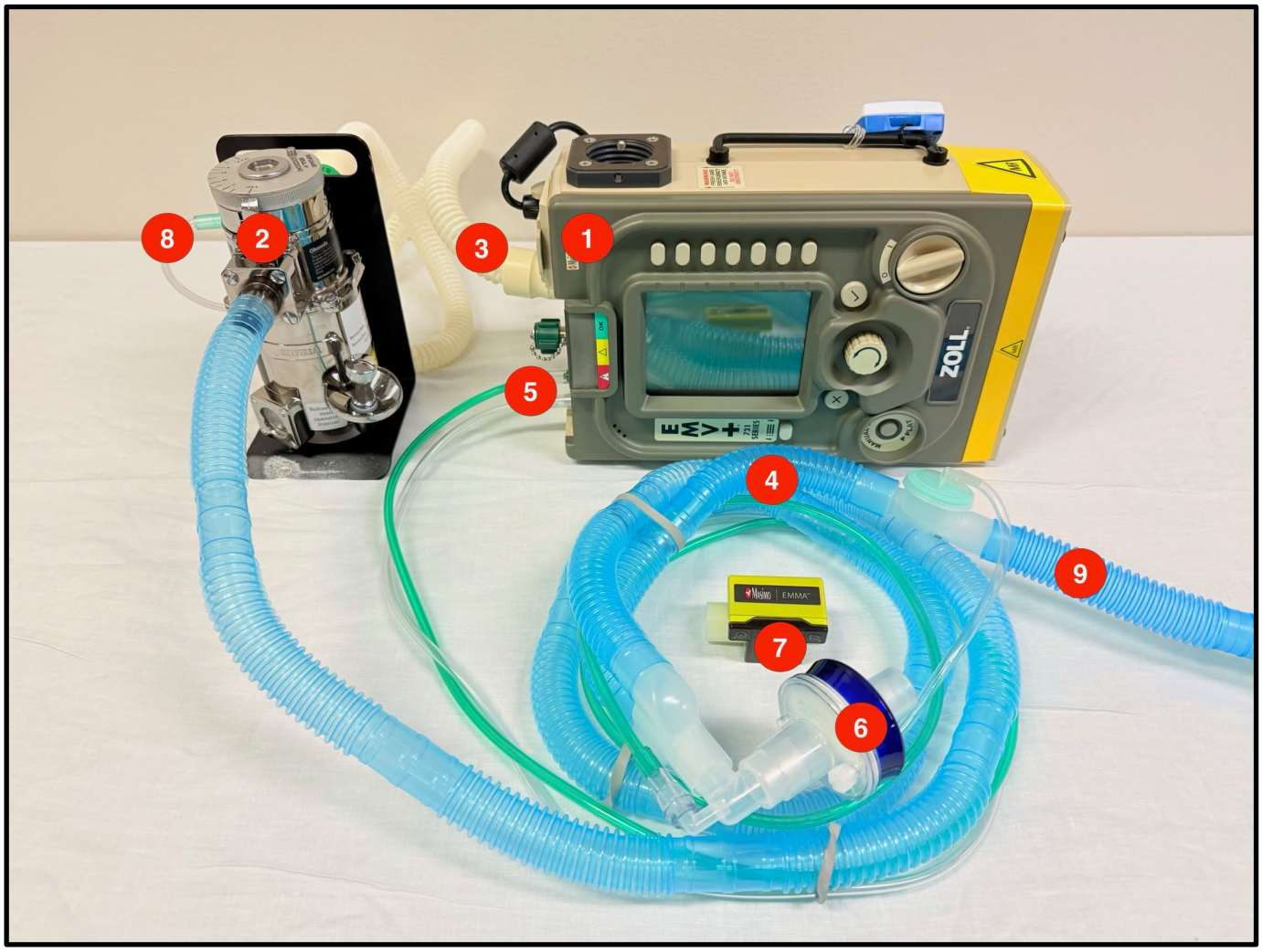


Figure 23. Complete setup 1) Impact 731 ventilator 2) UPAC drawover 3) UPAC patient circuit tubing 4) Standard Impact patient circuit 5) Expiratory check valve and Pressure transducer tubing. 6) HME filter 7) EMMA capnograph 8) O2 tubing 9) Scavenger tubing.

Comments: None.

E. Expected UPAC Vaporizer Delivered Agent Concentrations (Isoflurane)

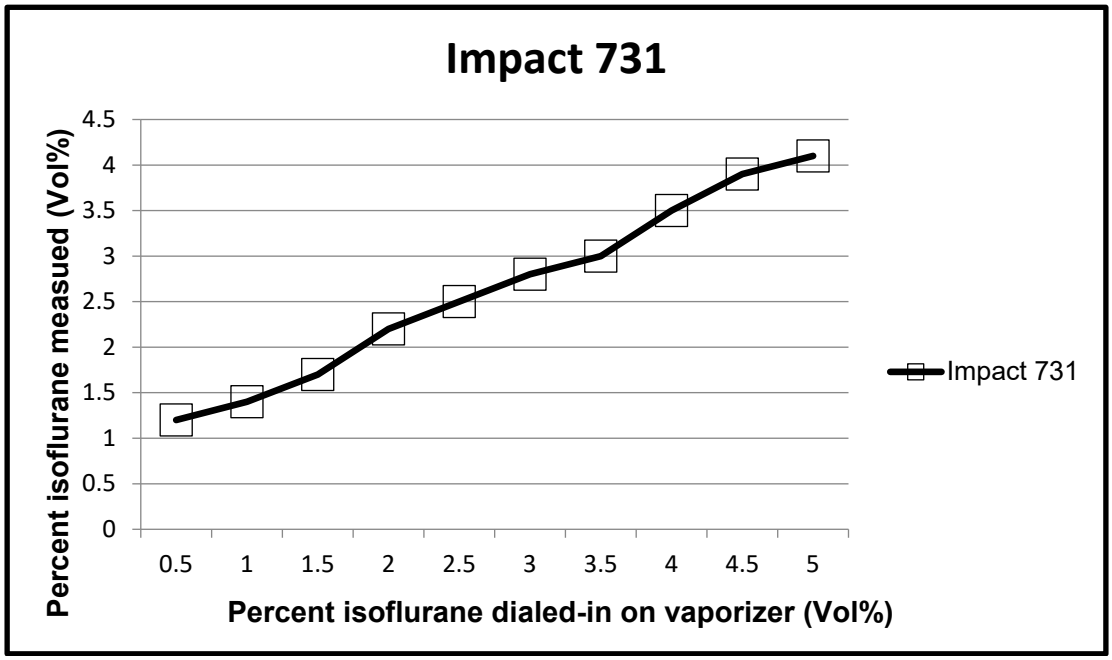


Figure 24. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

F. Bland-Altman Curve Graph for Isoflurane

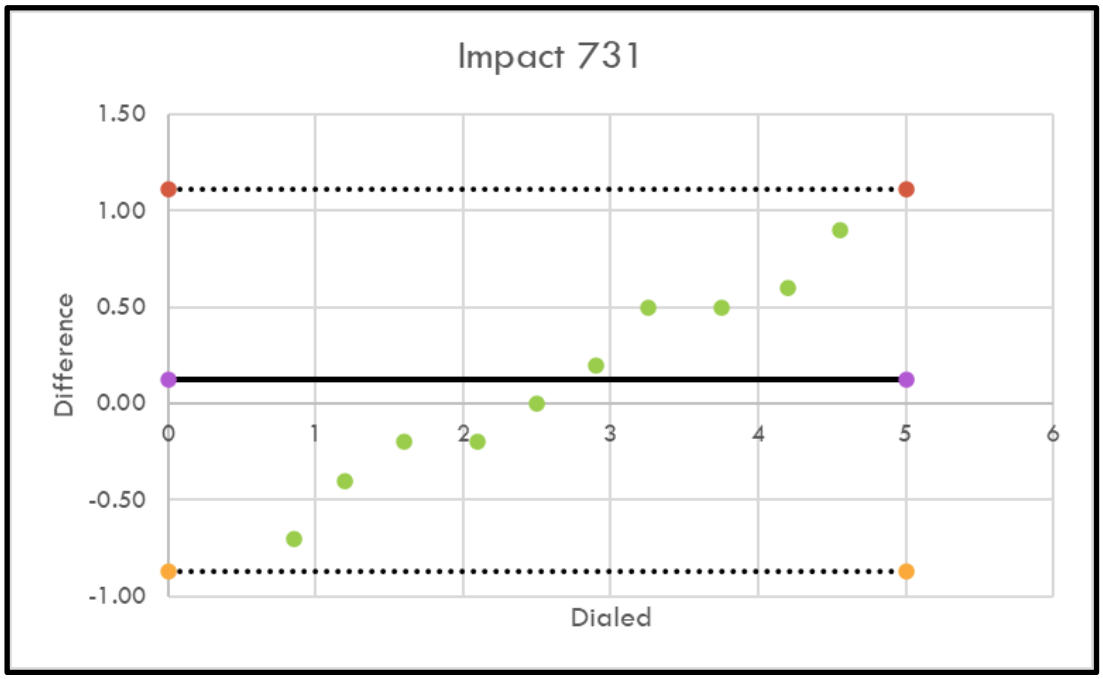


Figure 25. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

G. Troubleshooting

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

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.*

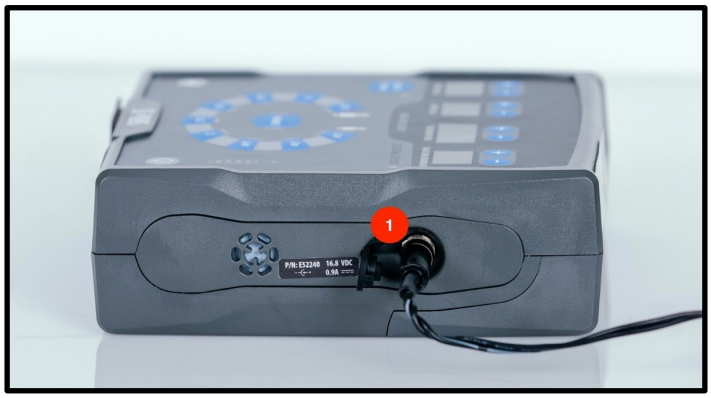


Figure 27. SAVe II ventilator power. 1) Power connection .

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 ("long 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

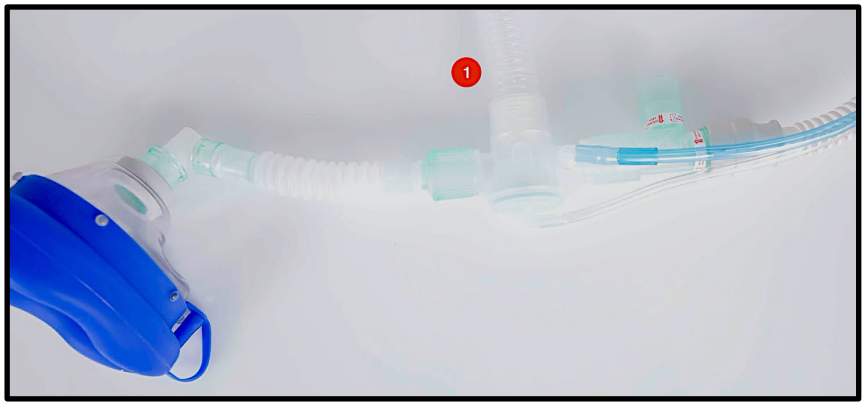


Figure 31. SAVe II standard circuit with corrugated tubing for scavenging connected. 1) Corrugated tubing for scavenging.

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

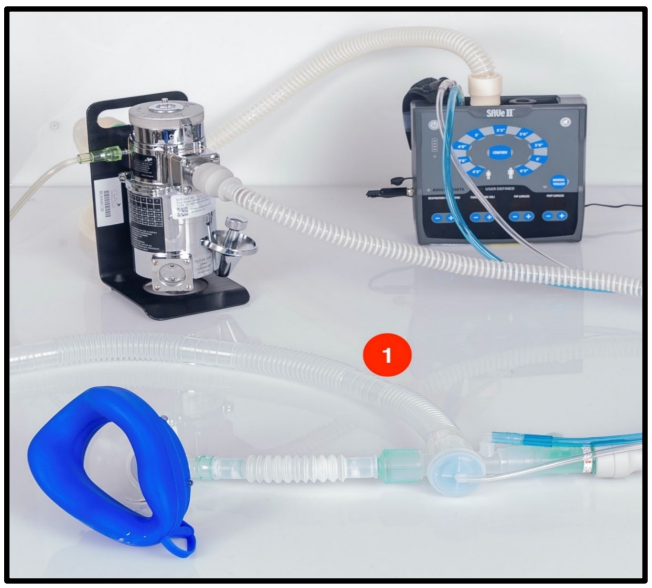


Figure 32. Complete setup of SAVe II with UPAC and scavenger tubing attached. 1) Scavenger tubing.

Comments: None



Figure 33. 1) EMMA capnagrophy sensor

Comments: When using the SAVeII ventilator use an EMMA capnography sensor or similar device capable of reading EtCO2.

E. Expected UPAC Vaporizer Delivered Agent Concentrations (Isoflurane)

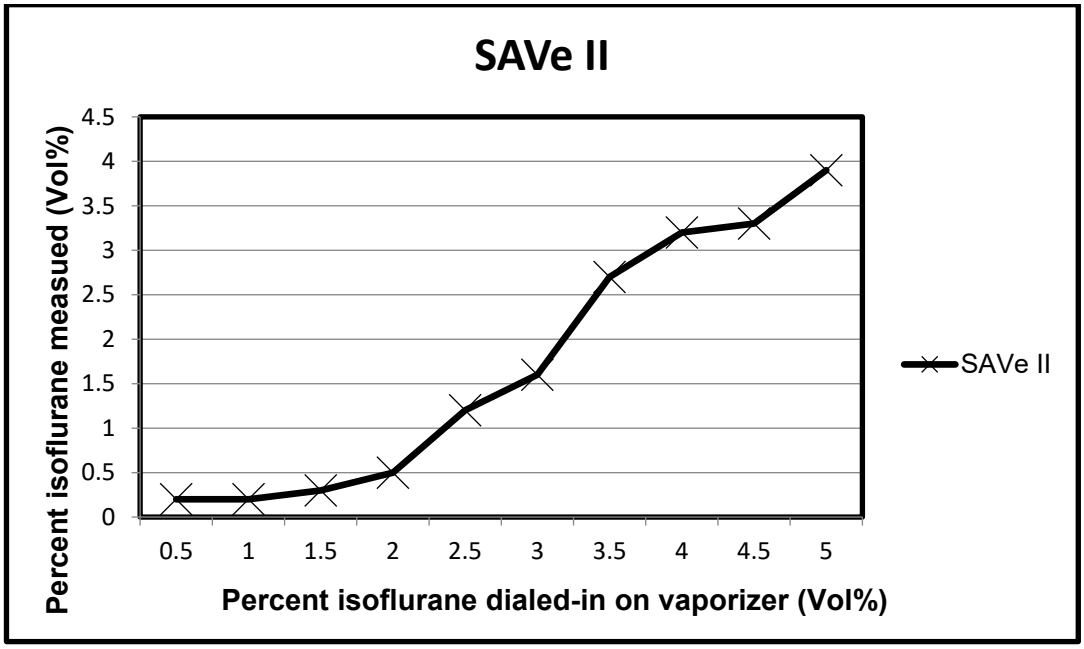


Figure 34. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

F. Bland-Altman Curve Graph for Isoflurane

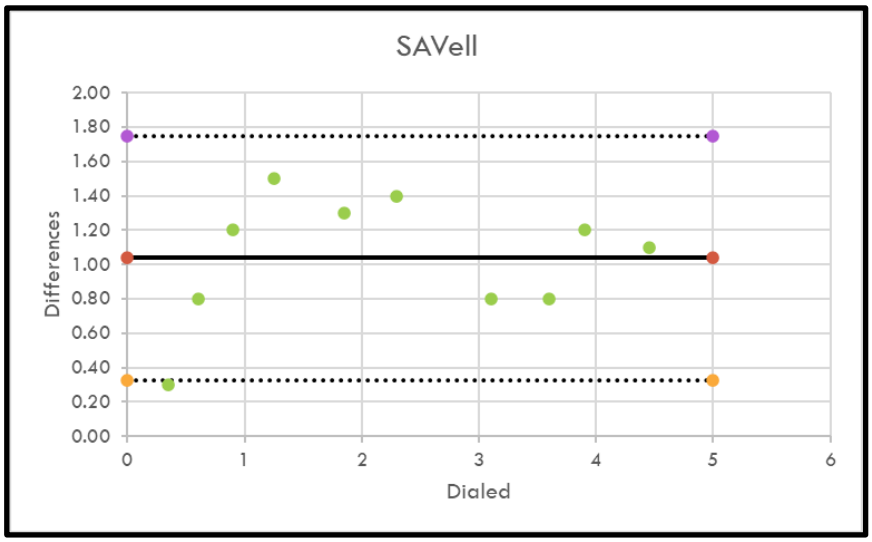


Figure 35. Adapted from: Benham BE, Kertes CSS. Compatibility of the Drawover Vaporizer with Military Field Ventilators. AANA J. 2021;89(2):125-132.[6]

VII. Manual Setup with Assisted Ventilation

A. Equipment

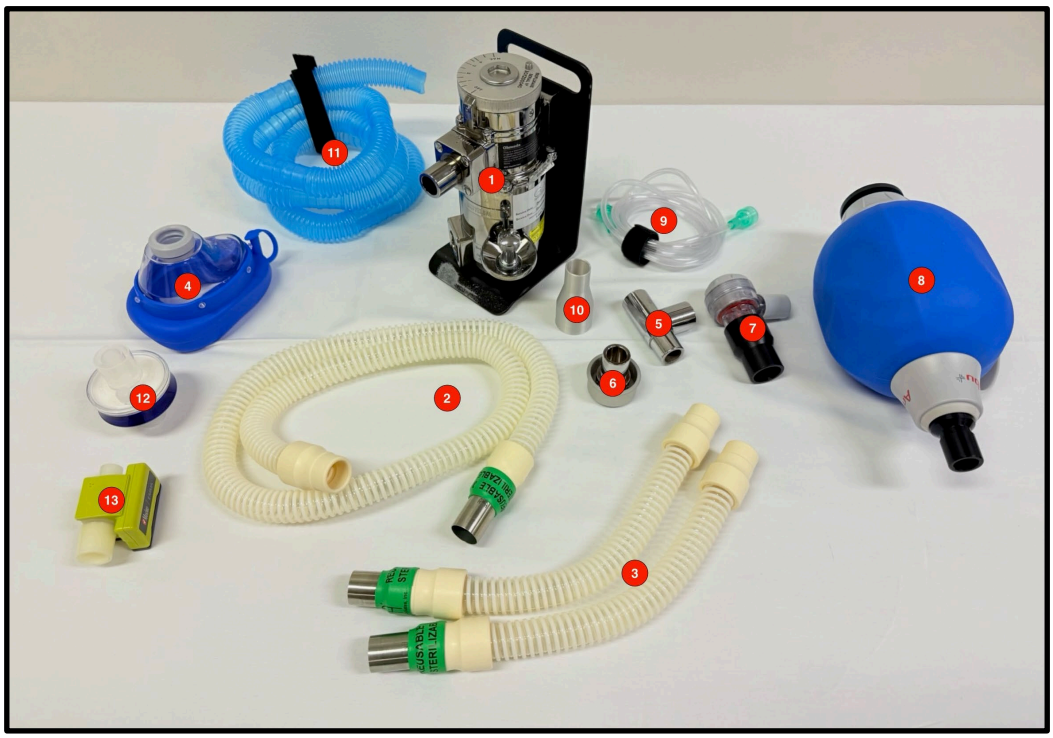


Figure 36. UPAC manual setup. 1) UPAC Drawover 2) UPAC patient circuit tubing 3) Oxygen concentrator and self-inflating bag tubing 4) Facemask 5) T connector 6) Oxygen reservoir dust cap 7) Unidirectional E-valve 8) Self-inflating bag 9) Oxygen tubing 10) Scavenger adaptor 11) Scavenger tubing 12) HME filter 13) EMMA EtCO2 sensor.

Comments: The Scavenger adaptor (Figure 36-10) is only available from G.A.S..

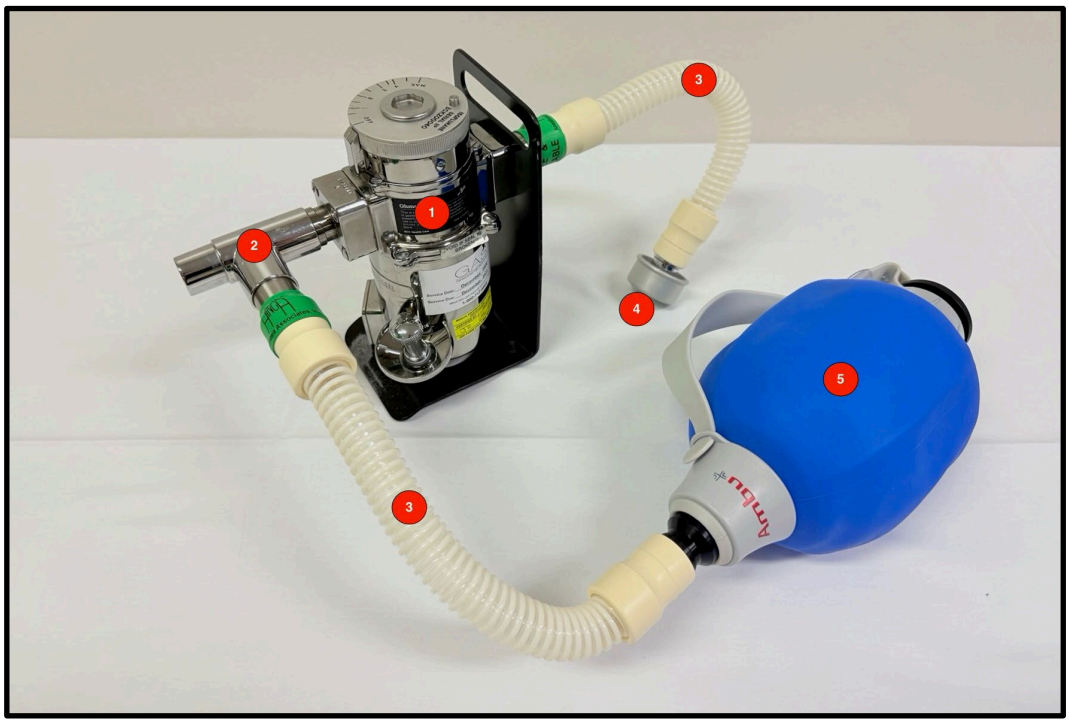


Figure 37. UPAC manual setup. 1) UPAC Drawover 2) T connector 3) Oxygen concentrator and self-inflating bag tubing 4) Oxygen reservoir dust cap 5) Self-inflating bag.

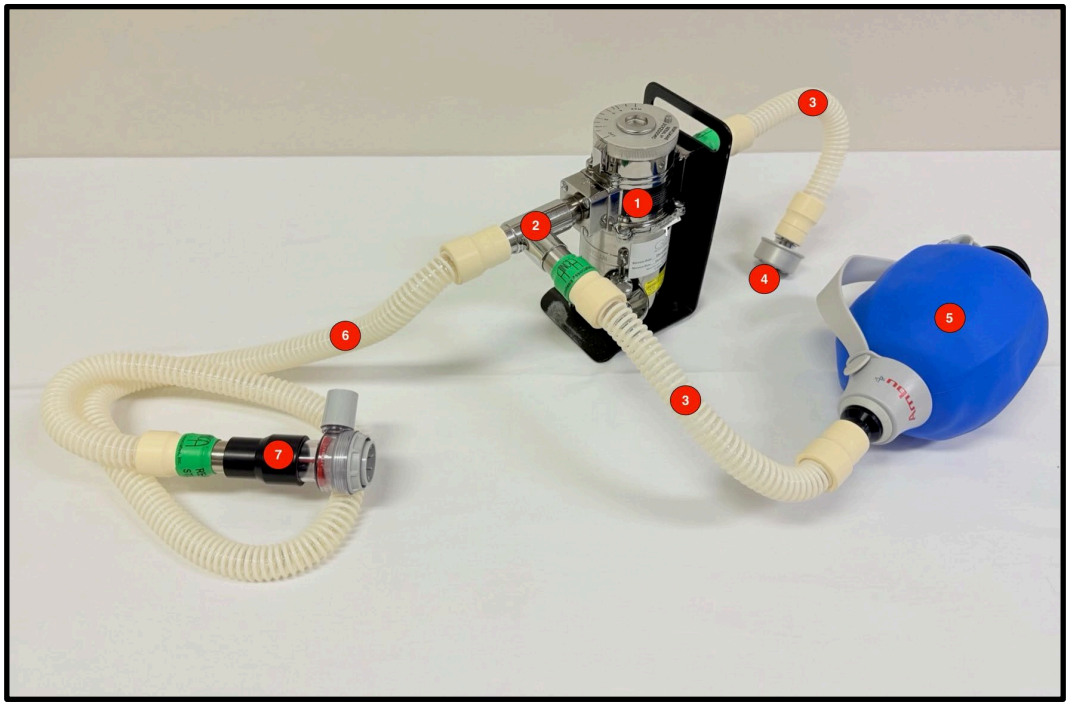


Figure 38. UPAC manual setup. 1) UPAC Drawover 2) T connector 3) Oxygen concentrator and self-inflating bag tubing 4) Oxygen reservoir dust cap 5) Self-inflating bag 6) UPAC patient circuit tubing 7) Unidirectional E valve.

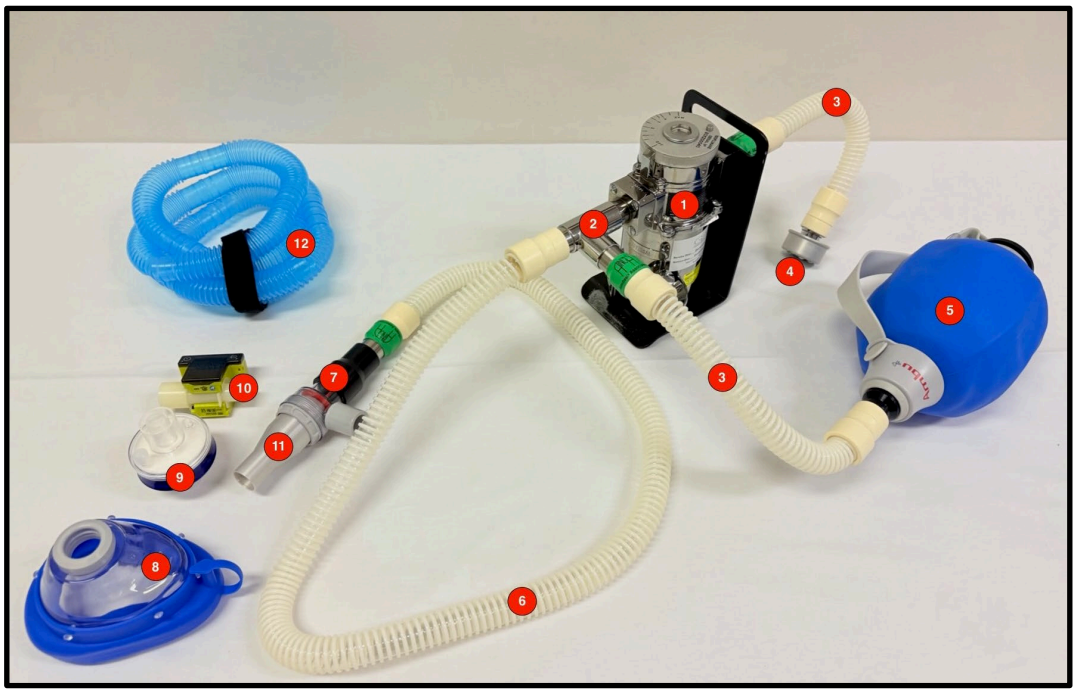


Figure 39. UPAC manual setup. 1) UPAC Drawover 2) T connector 3) Oxygen concentrator and self-inflating bag tubing 4) Oxygen reservoir dust cap 5) Self-inflating bag 6) UPAC patient circuit tubing 7) Unidirectional E valve 8) Facemask 9) HME filter 10) EMMA EtCO2 sensor 11) Scavenger adaptor 12) Scavenger tubing.

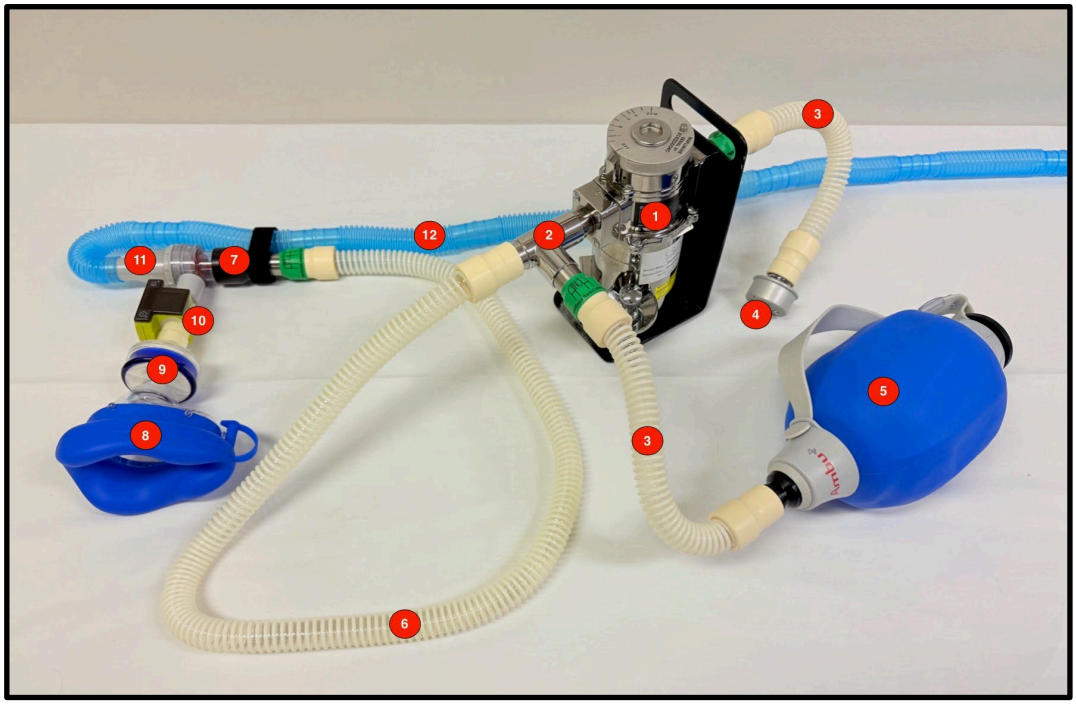


Figure 40. UPAC manual setup. 1) UPAC Drawover 2) T connector 3) Oxygen concentrator and self-inflating bag tubing 4) Oxygen reservoir dust cap 5) Self-inflating bag 6) UPAC patient circuit tubing 7) Unidirectional E valve 8) Facemask 9) HME filter 10) EMMA EtCO2 sensor 11) Scavenger adaptor 12) Scavenger tubing.

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 (Ambu-Bag or Jackson Rees) 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: How do you preoxygenate and mask ventilate the patient when using portable ventilator?

A: Preoxygenation can be achieved using a non-rebreather mask or by using a self-inflating resuscitating device such as a Ambu-Bag or Jackson Rees Circuit connected to an auxiliary oxygen source. The same setup should be used during emergence and extubation.

Q: How to measure EtCO2 when using the UPAC Drawover with the various ventilators?

A: Measuring EtCO2 can be accomplished by either using the CAPNOSTAT-5 Mainstream or Sidestream sensor for the HAMILTON-T1, a Sidestream sensor with supported Propaq Monitors, or the versatile and portable EMMA capnography sensor (Figure 29-1).

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. The pull-through configuration should **NOT** be used with the HAMILTON-T1 and is **highly discouraged**.

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

A: The HAMILTON-T1 UPAC pull-through configuration, when coupled with high pressure oxygen from a cylinder, has demonstrated excessively high peak inspiratory pressures and delivered tidal volume on multiple occasions in test scenarios. Specifically, during simulated emergence when changing from low FiO2 to >0.97 while using compressed oxygen from a high-pressure source (regulated H-cylinder or wall supply with pressure of 45-55 psi), it has been observed in numerous test scenarios that the HAMILTON-T1 delivers up to 90 cmH2O inspiratory pressure and excessively high tidal volumes. 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 any of these portable ventilators is unknown. Based on communication with the engineering branch at Hamilton Medical, using the T-1 and UPAC with this configuration is be considered **"off label use"** by the manufacturer. It is specifically omitted in the CPG and **SHOULD NOT BE USED IN THE PULL-THROUGH CONFIGURATION.**

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 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 6 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 anecdotal evidence and recent bench research study's unpublished secondary analysis data. If higher flow rates are possible, these values will increase as well.

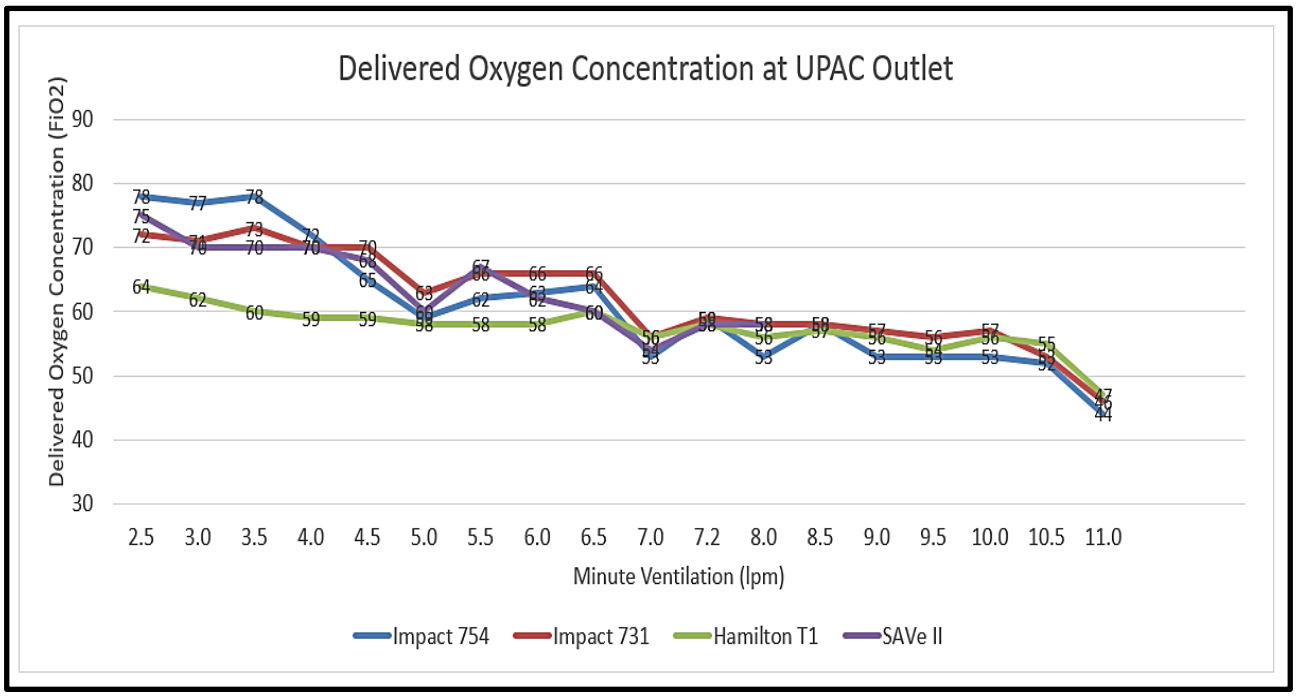


Figure 41. Adapted from: Benham BE Duffield B. A Multi-Faceted Analysis of Using the UPAC Vaporizer with the HAMILTON-T1 Transport Ventilator: Oxygen Enrichment, Push- and Pull-Through Operation, and Ventilator Contamination with Isoflurane Vapor. AANA J. 2023; 91(2): 47.[7]

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