Sudden Inability To Ventilate a Patient Shortly after Induction

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OBJECTIVES

Develop a strategy to rapidly and thoroughly evaluate and treat the inability to ventilate a patient.
Understand patient conditions that can lead to air leaks.
Develop a management plan in the event of an anesthesia machine failure.
Understand the FDA equipment checklist and its rationale.

STEM CASE - KEY QUESTIONS

A 68-year-old man presents for revision total hip arthroplasty. He weighs 120 kg, 185 cm tall, has mild CAD with NYHA Class I angina, smoker, moderate COPD, and diabetes mellitus II. Medications include glyburide, metoprolol, ASA and captopril. Airway exam reveals Mallampati 3 airway, own teeth, good cervical flexion & extension, 3 finger mouth opening and 4-finger thyromental distance. Cardiac exam is unremarkable. Respiratory exam reveals barrel chest, bilateral air entry with a prolonged expiratory phase and expiratory wheeze. The patient refuses a regional technique.

The patient is induced with propofol, fentanyl, and succinylcholine, easily ventilated with a bag and mask and intubated on the second attempt using a gum bougie intubating stylet. Bilateral air entry and presence of end tidal CO2 confirm ETT placement. The patient is placed on the ventilator and ventilated with N2O and O2 and preparations are made for positioning.

Shortly after placing the patient in the right lateral decubitus position he begins to cough. The sevoflurane is turned on to 4% and additional propofol is given. A low-pressure alarm sounds and the bellows are no longer filling….

What does the low-pressure alarm signify? Where is it measuring the pressure? What other alarms and abnormal findings will frequently be found with it?

What should you do now?

How do you isolate the problem?

How do you check a machine at the beginning of a day and between cases? What are the differences between machines?

What patient problems could result in an air leak?

PROBLEM BASED LEARNING DISCUSSION

Inability to ventilate an anesthetized patient can be broken down into inability to ventilate because there is an obstruction to gas flow (high airway pressures) and hypoventilation because the ventilatory system is losing volume and hypoventilating the patient (low airway pressures).

In the high airway pressure scenario, this may be due to patient problems and equipment problems. Airway obstruction (increased airway resistance) may be due to bronchospasm, air trapping/auto-PEEP, pneumothorax, or mucous plug/blood clot/pus in the airway. Alternatively, decreased compliance of the lung is typically due to an interstitial/intra-alveolar process that at its simplest can be due to water, blood or pus. Water, may arise from increased intracapillary pressure due to pulmonary venous outflow obstruction, or increased pulmonary artery pressure. It may be due to leaky capillary walls, usually due to an inflammatory process, e.g. ARDS, SIRS, chemical pneumonitis, etc. Blood may arise due to frank hemorrhage (from tumor, vessel rupture, traumatic injury), from a marked inflammatory process that is leading to breakdown of the alveolar membranes (e.g. in hemorrhagic fevers, ARDS, pneumonia, etc), or spontaneous hemorrhage in the face of marked coagulopathy. Finally pus, as part of an infectious process may also lead to an intra-alveolar obliteration and decreased compliance.

Equipment problems leading to high airway pressures would occur from the common gas outlet distally. Within the circle system, if the pop-off valve is completely closed, airway pressures will rise, although the reservoir bag will provide some protection, with airway pressures typically plateauing at approximately 50 cm H2O. Errors in setting the ventilator or ventilator malfunction resulting in delivery of inappropriately high tidal volumes may result in high airway pressure even in the face of a normal pulmonary system. Unidirectional valves switched so that the expiratory valve is on the inspiratory limb and vice versa will result in inability to move gas forward through the circuit. Finally kinks or any sort of obstruction in the tubing of the circle system will lead to obstruction of gas flow. Problems that may arise from the endotracheal tube include a bent, kinked, bitten tube, a tube obstructed by debris intraluminally, a tube jammed up against a tracheal wall, balloon herniation over the end of the tube, or malposition either endobronchially. Finally malposition of the tube, e.g. esophageally, or into blind passage may present with inability to ventilate with elevated airway pressure.

In this patient we are presented with an inability to ventilate and low airway pressures. I find that a totally geographic approach as outlined in the following table is the simplest way to present a clear and thorough check.

Patient: - bronchopleural fistula
- bronchial/tracheal tear
- high airway resistance and pressures leading to “venting” around cuff

Endotracheal tube: -tube displaced into hypopharynx
- esophageal intubation
- cuff leak/tear
- normal “venting” in an uncuffed tube
- leak in tube

Circle system: - Y-connection: -disconnect
- sampling by gas analyzer
- tubing: holes/kinks/melting/manufacturing defect
- disconnect or loose connection
- A/W press sensor: misconnect
- leak in pressure sensing tubing
- spirometer: misconnect
-device malfunction
-leak in tubing if differential pressure device

Unidirectional valves: screw locks loose

APL valve: -set improperly
-active scavenger malfunction

Bag: - hole in bag
-misconnected bag

CO_2 absorber: -cartridges seated incorrectly
-granules on O-ring
-cracked cartridge

Low-pressure circuit: tubing and fitting holes or misalignment or disconnect

Vaporizer:- internal leak
-misalignment on back bar
-leak at O-rings on back bar
-open filler cap

Flow meter: -cracked
-leak at O-ring between tube and manifold

High pressure circuit: -leak in tubing or at fittings
-loss of supply

Ventilator: -bellows leak (missed in falling bellows)
-scavenging system/ventilator relief valve malfunction
-failure to close pressure relief valve (on old machines)

Inability to ventilate a patient intraoperatively is an anesthetic emergency. Diagnosis and therapy must be carried out simultaneously. A differential diagnosis was covered above. Treatment would consist of isolating the system in a stepwise fashion. First switching from the ventilator to hand bagging, both to eliminate the ventilator from the system as well as to “feel” the ventilatory system. Switching to 100% O_2 will eliminate more complexity (the N_2O delivery system as well as the vaporizers) from the system as well as provide a more oxygen rich environment if partial ventilation is occurring. Survey for presence of end tidal CO_2 as confirmation of endotracheal tube placement as well as auscultation and if there are any doubts consideration of extubation

and either reintubation or ventilation with a mask. Finally having a low threshold to switch from an anesthesia machine to a stand alone resuscitation bag and oxygen supply is prudent.

Prevention should be our goal rather than rescue. In 1993, the FDA developed a checklist for the anesthesia machine that continues to be germane and thorough:

FDA Anesthesia Apparatus Checkout - 1993

This checkout, or a reasonable equivalent, should be conducted before administration of anesthesia. These recommendations are only valid for an anesthesia system that conforms to current and relevant standards and includes an ascending bellows ventilator and at least the following monitors: capnograph, pulse oximeter, oxygen analyzer, respiratory volume monitor (spirometer) and breathing system pressure monitor with high and low pressure alarms. This is a guideline which users are encouraged to modify to accommodate differences in equipment design and variations in local clinical practice. Such local modifications should have appropriate peer review. Users should refer to the operator's manual for the manufacturer's specific procedures and precautions, especially the manufacturer's low pressure leak test

Emergency Ventilation Equipment
*1.**Verify Backup Ventilation Equipment is Available & Functioning**

High Pressure System

*2. **Check Oxygen Cylinder Supply**

a. Open 0_2 cylinder and verify at least half full (about 1000 psi).
b. Close cylinder.

*3. **Check Central Pipeline Supplies**
a. Check that hoses are connected and pipeline gauges read about 50 psi.

Low Pressure Systems
*4. **Check Initial Status of Low Pressure System**
a. Close flow control valves and turn vaporizers off.
b. Check fill level and tighten vaporizers' filler caps.

*5. **Perform Leak Check of Machine Low Pressure System**
a. Verify that the machine master switch and flow control valves are OFF.
b. Attach "Suction Bulb" to common Fresh gas outlet.
c. Squeeze bulb repeatedly until fully collapsed.
d. Verify bulb stays fully collapsed for at least 10 seconds.
e. Open one vaporizer at a time and repeat 'c' and 'd' as above.
f. Remove suction bulb, and reconnect fresh gas hose.

*6. **Turn On Machine Master Switch and all other necessary electrical equipment.**

*7. **Test Flowmeters**

a. Adjust flow of all gases through their full range, checking for smooth operation of floats and undamaged flowtubes.

b. Attempt to create a hypoxic $0_2/N_20$ mixture and verify correct changes in flow and/or alarm.

Scavenging System

*8. **Adjust and Check Scavenging System**

a. Ensure proper connections between the scavenging system and both APL (pop-off) valve and ventilator relief valve.

b. Adjust waste gas vacuum (if possible).

c. Fully open APL valve and occlude Y-piece.

d. With minimum 0_2 flow, allow scavenger reservoir bag to collapse completely and verify that absorber pressure gauge reads about zero.

e. With the 0_2 flush activated allow the scavenger reservoir bag to distend fully, and then verify that absorber pressure gauge reads <10 cm H_20.

Breathing System

*9. **Calibrate 0_2 Monitor**

a. Ensure monitor reads 21% in room air.

b. Verify low 0_2 alarm is enabled and functioning.

c. Reinstall sensor in circuit and flush breathing system with 0_2.

d. Verify that monitor now reads greater than 90%.

10. **Check Initial Status of Breathing System**

a. Set selector switch to “Bag” mode.

b. Check that breathing circuit is complete, undamaged and unobstructed.

c. Verify that $C0_2$ absorbent is adequate.

d. Install breathing circuit accessory equipment (e.g. humidifier, PEEP valve) to be used during the case.

11. P**erform Leak Check of the Breathing System**

a. Set all gas flows to zero (or minimum).

b. Close APL (pop-off) valve and occlude Y-piece.

c. Pressurize breathing system to about 30 cm H_20 with 0_2 flush.

d. Ensure that pressure remains fixed for at least 10 seconds.

e. Open APL (Pop-off) valve and ensure that pressure decreases.

12. **Test Ventilation Systems and Unidirectional Valves**
    a. Place a second breathing bag on Y-piece.
    b. Set appropriate ventilator parameters for next patient.
    c. Switch to automatic ventilation (Ventilator) mode.
    d. Fill bellows and breathing bag with 0_2 flush and then turn ventilator ON.
    e . Set 0_2 flow to minimum, other gas flows to zero.
    f. Verify that during inspiration bellows delivers appropriate tidal volume and that during expiration bellows fills completely.
    g. Set fresh gas flow to about 5 L/min.
    h. Verify that the ventilator bellows and simulated lungs fill and empty appropriately without sustained pressure at end expiration.
    i. Check for proper action of unidirectional valves.
    j. Exercise breathing circuit accessories to ensure proper function.
    k. Turn ventilator OFF and switch to manual ventilation (Bag/APL) mode.
    l. Ventilate manually and assure inflation and deflation of artificial lungs and appropriate feel of system resistance and compliance.
    m. Remove second breathing bag from Y-piece.

Monitors

13. **Check, Calibrate and/or Set Alarm Limits of all Monitors**

    Capnometer
    Pulse Oximeter
    Oxygen Analyzer
    Respiratory Volume Monitor (Spirometer)
    Pressure Monitor with High and Low Airway Alarms

Final Position

14. **Check Final Status of Machine**
    a. Vaporizers off
    b. AFL valve open
    c. Selector switch to “Bag”
    d. All flowmeters to zero
    e. Patient suction level adequate
    f. Breathing system ready to use

REFERENCES

Caplan RA, Vistica MF, Posner KL, et al: Adverse anesthetic outcomes arising from gas delivery equipment: A closed claims analysis. Anesthesiology 1997; 87:741-8.

Eisenkraft JB: A commentary on anesthesia gas delivery equipment and adverse outcomes. Anesthesiology 1997; 87:731-3.

www.simanest.org This site provides a free simulator of an anesthesia machine showing different pathways and potential for leaks and malfunctions. It also has a few other interesting simulations.

www.fda.gov//cdrh/humfac//anesckot.html The official 1993 FDA anesthesia machine checklist

www.asahq.org/wlm/VirtualTour/Node5.html An interesting site by our own ASA Wood Library with some historical aspects of the anesthesia machine.

Dorsch JA, Dorsch SE: Understanding Anesthesia Equipment, Baltimore, Williams & Wilkins, 1999: pp75-120, 166-174, 230-233, 237-253, 310-313, 317-351, 402-409, 592-593, 600, 937-958

LEARNING SUMMARY

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