Ventilator Test Protocol – Stage 1 Test - V0.1 - 4/7/20 - D Lizdas, T Destephens

Items needed

- Imt Medical Citrex H5 (Citrex)
- Michigan Test Lung (MTL), one bellows, verified with volume syringe
- #8 Endotracheal tube connected to MTL
- Double-hose anesthesia breathing circuit (anticipated availability during covid crisis)
- Pressure regulator on ventilator closed fully (knob unscrewed, counterclockwise, no flow)
- Wall oxygen at 50 PSI
- Exhalation port plug
- Exhalation port to 36” hose for bubble leak test

Standard Test Configuration:

- Ventilator connected to 50 PSI gas supply
- Ventilator connected to MTL via anesthesia breathing circuit and 8.0 Endotracheal tube
- Citrex between Y piece and ETT
- MTL set to normal compliance
- MTL one bellows
- no PEEP

**Exhalation Limb Flow Resistance Test**
configuration: Citrex connected to ventilator expiratory 22mm port, 60 LPM air source connected to Citrex, 60 LPM air source turned OFF, ventilator controller off, Ventilator inspiratory port open to air

- Ventilator regulator at 20 PSI
- Manually open inspiratory valve one quarter turn for 2 seconds to cycle expiratory valve
- Open 60 LPM air source valve
- Adjust air source to 60 LPM using Citrex flow sensor measurement (60 LPM +/- 1 LPM)
- Verify Citrex pressure below 3.8 cmH2O
- Log pressure from Citrex

**Positive pressure leak test**
configuration: Standard Test Configuration

- ventilator controller off
- plug exhalation port
- Regulator to 20 PSI
- Manually adjust inspr valve to fill MTL to 1200 mL, then close inspr valve
- Wait 30 seconds; leak test passed if MTL remains at 1200 mL for 30 sec
- Log pressure from Citrex

**Positive pressure seal test**
configuration: Standard Test Configuration
ventilator controller off
Disconnected breathing hose from inspr limb
Regulator to 30 PSI
Manually open inspr valve on quarter turn
Wait 5 seconds; seal test passed if no separation occurs
Regulator back to 0 psi, manually close inspr valve

Exhalation valve blow-by Leak Test
classification: Standard Test Configuration
Remove PEEP valve from exhalation limb
Regulator to 20 PSI
Ventilator controller to RR15, IE 1:2
Connect tube from exhalation limb exit to 1 cmH2O hydrostatic head (water in flask, end of tube no more than 1 cm under water)
Verify no bubbles during inhalation cycle (some bubbles expected during the initial quarter-second of inspiratory cycle as exhalation valve fills and seals)

Ventilator Settings and Overpressure Test
classification: Standard Test Configuration
Verify TV is adjustable; verify measured TV error is acceptable
  o Ventilator on, RR 15, IE 1:2
    o Attempt 250 ml TV. adjust regulator pressure until 250 ml as read on Citrex.
      ▪ Test measured tidal volume: volume should report between 225 to 275 ml
      ▪ Log 15 seconds of Citrex data
    o Attempt 800 ml TV. adjust regulator pressure until 800 ml as read on Citrex.
      ▪ Test measured tidal volume: volume should report between 775 to 825 ml
      ▪ Log 15 seconds of Citrex data
    o Attempt 500 ml TV. adjust regulator pressure until 500 ml as read on Citrex.
      ▪ Test measured tidal volume: volume should report between 475 to 525 ml
      ▪ Log 15 seconds of Citrex data
Verify RR is adjustable, and RR is accurate
  o Adjust RR to 10, 20, and 30; check cycle count with stopwatch
Verify IE is adjustable and IE timing is accurate
  o Adjust IE to 1:2 and 1:1; check I:E split
Verify PEEP valve is adjustable and measured airway pressure is accurate
  o RR 10, IE 1:2
    o Add PEEP valve, set to PEEP 5, 15, and 30 cmH2O using airway pressure sensor
    o Compare airway pressure sensor reading to Citrex PEEP, difference should be no more than 1 cmH2O
Verify Overpressure relief valve
  o Ventilator controller off
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- Set MTL compliance to 0.02 L/cmH2O (protects MTL bellows from overtravel)
- Remove PEEP valve, plug expiratory port
- Adjust overpressure relief valve to max
- Manually open inspiratory valve, stop if pressures reach 100 cmH2O
- Verify airway pressure on Citrex not over 65 cmH2O
- Manually adjust overpressure valve to min
- Verify airway pressure on Citrex between 35 – 45 cmH2O

**Ventilator Anti-Asphyxia Test**
configuration: Citrex between Y piece and 1L calibration syringe

- Ventilator controller off
- Close 1L calibration syringe
- Pull 1L calibration syringe open in one second, use stopwatch
- Check anti-asphyxia valve opens and airway pressure did not drop below – 3 cmH2O

**Alarms Test**
configuration: Citrex between Y piece and MTL set to normal compliance, one bellows, no PEEP, ventilator controller turned on

- Verify Patient Disconnect condition triggers alarms in low flow vent settings
  - Alarms Test base configuration
  - Vent settings: RR 12, IE 1:2, TV 250 mL, no PEEP
  - While ventilator is running, disconnect breathing circuit from 22mm inspr limb
  - Wait 4 seconds for audible alarm and UI to display “LOW AIRWAY PRES!” and “SET TV NOT DELIV”
  - Reconnect breathing circuit
  - Wait 4 seconds for audible alarm and UI display “LOW AIRWAY PRES!” and “SET TV NOT DELIV” to clear
  - Repeat test, disconnect breathing circuit from 22mm expr limb
  - Repeat test, disconnect breathing circuit Y-piece from MTL
- Verify Patient Disconnect condition triggers alarms in high flow vent settings
  - Alarms Test base configuration
  - Vent settings: RR 30, IE 1:2, TV 800 mL, no PEEP
  - While ventilator is running, disconnect breathing circuit from 22mm inspr limb
  - Wait 4 seconds for audible alarm and UI to display “LOW AIRWAY PRES!” and “SET TV NOT DELIV”
  - Reconnect breathing circuit
  - Wait 4 seconds for audible alarm and UI display “LOW AIRWAY PRES!” and “SET TV NOT DELIV” to clear
Repeat test, disconnect breathing circuit from 22mm expr limb
Repeat test, disconnect breathing circuit Y-piece from MTL

**Verify Loss of Gas Supply Pressure condition triggers alarms in low flow vent settings**
- Alarms Test base configuration
- Vent settings: RR 12, IE 1:2, TV 250 mL, no PEEP
- While ventilator is running, disconnect gas supply to ventilator at wall supply connection
- Wait 4 seconds for audible alarm and UI to display “LOW AIRWAY PRES!” and “SET TV NOT DELIV”
- Reconnect gas supply to ventilator
- Wait 4 seconds for audible alarm and UI display “LOW AIRWAY PRES!” and “SET TV NOT DELIV” to clear

**Verify High inspiratory airway pressure alarm:**
- Alarms Test base configuration
- Set MTL to low lung compliance (0.02 L/cmH2O)
- Adjust high inspiratory airway pressure alarm limit to 15 mH2O
- Ventilator on and connected to MTL
- Vent settings: RR 15, IE 1:2, TV 800 mL, PEEP 10
- Wait 2 seconds for audible alarm and UI to display “OVER PRES ALARM!” and “LOW VT, IT SHORTENED”
- Inspiratory solenoid valve should close to stop inspiratory flow
- verify pressure in the inspiratory circuit does not go above 16 cmH2O during inspiration using Citrex
- Adjust high inspiratory airway pressure alarm limit to 35 cmH2O (default)
- Wait 4 seconds for audible alarm and UI “OVER PRES ALARM!” and “LOW VT, IT SHORTENED” to clear

**Verify TV High alarm:**
- Alarms Test base configuration
- Set TV high alarm limit to 400mL
- Turn ventilator on and connect to MTL
- Vent settings: RR 15, IE 1:2, TV 500 mL
- Wait 4 seconds for audible alarm and UI to display “TV HIGH”
- Set TV high alarm limit to 1000mL
- Wait 4 seconds for audible alarm and UI display “TV HIGH” to clear

**Verify TV Low alarm:**
- Alarms Test base configuration
- Set TV low alarm limit to 400mL
- Turn ventilator on and connect to MTL
- Vent settings: RR 15, IE 1:2, TV 300 mL
- Wait 4 seconds for audible alarm and UI to display “SET TV NOT DELIV”
- Set TV low alarm limit to 200mL
- Wait 4 seconds for audible alarm and UI display “SET TV NOT DELIV” to clear
Backup Battery test

configuration: Citrex between Y piece and MTL set to normal compliance, one bellows, no PEEP

• Verify Ventilator can run for 30 minutes on backup battery power
  o Ventilator on, RR 30, IE 1:2
  o Set TV low alarm limit to 800mL to create constant alarm (max battery drain)
  o Attempt 500 ml TV. adjust regulator pressure until 500 ml as read on Citrex.
    ▪ Log 15 seconds of Citrex data
    ▪ Log 15 seconds of Citrex data after 30 minutes