Respiratory Care Pocket Reference

v2021.11

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By collaborators & with support from multiple institutions, including:

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Oxygen Sources & Delivery Devices

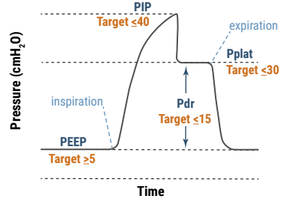
Nasal Cannula (NC)	**Pros:** Ubiquitous; commonly used up to 6LPM **Cons:** Requires humidification if >4LPM (risk of epistaxis); no work of breathing support **O_2:** works with any pressure source via flow meter; FiO_2 increases 2-4% per LPM; variable FiO_2 delivery based on patient's minute ventilation & flow rate
Non-Rebreather/ Face mask (NRB/FM)	**Pros:** ~High FiO_2; can be more comfortable than NC **Cons:** Limited FiO_2 if high respiratory drive; no work of breathing support **O_2:** works with any pressure source via flow meter; simple FM 5-10 LPM (~FiO_2 35-50%); NRB 10-15 LPM (~FiO_2 60-80%); enough flow to prevent bag collapse
High Flow Nasal Cannula (HFNC)	**Pros:** High FiO_2 even with high minute ventilation; can titrate flow and FiO_2; heated and humidified for comfort; may improve outcomes in acute hypoxemic respiratory failure compared to NIPPV or low-flow O_2; small amount positive pressure may help with recruitment; high flow = deadspace washout, may help with work of breathing **Cons:** Requires special device; consumes massive amounts of oxygen **O_2:** Requires high pressure/flow source; ~ >90% FiO_2 (variable with minute ventilation, entraining room air around cannula) 3 types: 1) With blender to mix compressed air + O_2; 2) With port/Venturi effect to entrain room air and mix with compressed O_2; or 3) Without blender. **Initial Settings:** infant <1year = 8LPM; child 1-4 years = 10LPM; Child > 4 years = 20LPM; adolescents/adults = 40LPM flow and 100% FiO_2; can titrate flow and/or FiO_2 (max flow depends on cannula size; up to 60 LPM for adults and 100% FiO_2) if tolerated and O_2 source adequate.
Non-invasive Ventilation (NIV) **or Positive Pressure Ventilation** (NIPPV) Trade name "BiPAP"	**Pros:** May avoid intubation in some patients (COPD, cardiogenic pulmonary edema, upper airway obstruction) by decreasing work of breathing and adding PEEP **Cons:** Risk of infectious aerosol generation (possibly less if helmet NIPPV); risk of aspiration if patient not alert / unable to protect airway or if inspiratory pressures ≥20cm H_2O; pt must be alert enough to remove mask if uncomfortable; skin breakdown with prolonged use; confusing terminology: IPAP (inspiratory pressure); EPAP (expiratory pressure = PEEP); PS of "5 over 5" is the same as PS delta 5 over 5, is the same as IPAP 10/EPAP 5 **O_2:** requires high pressure/flow source to achieve high FiO_2 **Initial Settings:** PS (DP) 5/PEEP (EPAP) 5-10; titrate DP up to 15 to reduce inspiratory work; use higher initial IPAP with obese patients; higher pressures may require sedation in pediatric patients
Continuous Positive Airway Pressure (CPAP)	**Pros:** Delivered via face mask or multiple other potential interfaces to splint open the upper airway, increase lung volume & intrathoracic pressure Cons: Prolonged use is uncomfortable & causes skin breakdown; limited unloading of inspiratory muscles or provide complete respiratory support **O_2:** requires high flow/pressure source to achieve high FiO_2 **Initial Settings** (adults/peds): CPAP or PEEP 5-10; adults: titrate as needed up to 15; peds ≤12; higher pressures may require sedation in peds

Oxygen Delivery Device & Supply FAQ

Oxygen Supply & Demand Calculator

Respiratory Mechanics

Positive End Expiratory Pressure (PEEP)	• Pressure within respiratory circuit at end of expiration • Must be ≥5 cm H_2O in IMV to prevent derecruitment of alveoli • This value is **always** set by ventilator operator
$Pressure_{Peak\ Inspiratory}$ (PIP)	• Reflects pressure generated by airway/ETT resistance and compliance • Range 10-40cm H_2O; **target <40cm H_2O**
$Pressure_{Plateau}$ (Pplat)	• Reflects pressure in alveoli only • If in volume control, perform inspiratory pause (when there is no flow, there is no effect of resistance; Pplat = Pressure at alveoli • **Target <30cm H_2O (adults); <28 (peds);** optimal ≤25 cm H_2O
$Pressure_{Driving}$ (Pdr)	• Pdr = Pplat - PEEP • Tidal stress (lung injury and mortality risk) if elevated • **Target ≤15cm H_2O;** mortality risk if ≥20cm H_2O
I:E and Inspiratory Time (T_I)	• I:E = ratio of Inspiration to Expiration • Normal 1:2 or 1:3, 1:1 is only tolerated when paralyzed (and rarely indicated), 1:4 or 1:5 may be better in asthma or COPD • Normal Ti ~ 1-1.5s in non ARDS; Consider Ti 0.7-1 for ARDS
Minute Ventilation (MV)	• MV = V_T x RR; where V_T is the **tidal** volume (i.e. volume of each breath) and RR is the **respiratory rate** (breaths per minute) • Normal 4-6 LPM; ~lower if obtunded, hypothermic, deeply sedated; ~higher 8-14 LPM in hypoxemic respiratory failure • Adjust for pCO, goal (e.g. permissive hypercarbia if ARDS); ~6-8 L/min in most intubated adults, may be ≥10-15 L/min in ARDS
Peak Flow	• Highest flow delivered by ventilator during inspiration • 40-60 LPM common; ~50-80 LPM if patient triggered mode • Sometimes increasing flow can improve patient-ventilator synchrony; **caution this may cause elevation in PIP**
Compliance (C)	• C = ΔV / ΔP = Tidal volume of breath / Pdr • **Dynamic compliance** (VT/PIP-PEEP) or **static compliance** (VT/Pplat-PEEP) measured at end inspiratory pause • Range is 60-80mL/cm H_2O in intubated patients; ARDS ≤40
Inspiratory Resistance (R)	• R = PIP - Pplat/inspiratory flow • Must be measured during constant flow • Normal <10cm H_2O/L/sec; **concern if ≥15cm H_2O/L/sec**

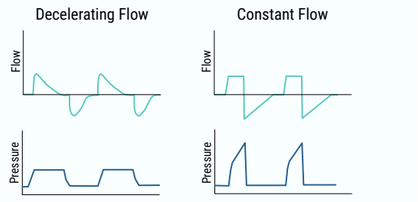


Choosing a Ventilator Mode

- **Assist Control (AC) Volume Mode** is default for non-spontaneous breathing patients or ARDS
- **AC Pressure Mode & Dual Modes** can be used for non-spontaneous breathing patients or ARDS
- **PSV** if spontaneous breathing and non-ARDS; **SIMV** and **APRV** have no data to support regular use

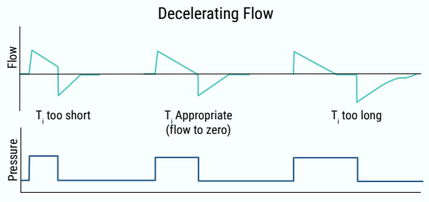
Volume Control

Other Names	AC-VC; Assist Control Volume Control; VCV; ~CMV (controlled mandatory ventilation = all modes with RR and fixed T_I); (S)CMV
Controlled Variables	**RR, V_T,** PEEP, FiO_2,Trigger level, Flow pattern, I:E (either directly or via peak flow, T_I settings)
Initial Settings Adult & Pediatric (More details on next page)	1. Set V_T at 6-8 mL/kg predicted body weight (PBW) 2. Set RR: Adults: set at pt's most recent RR (do not exceed 35); **Peds: set at most recent RR (do not exceed 60 bpm in infants, 40 bpm in toddlers/preschoolers,** 35 bpm in **school-aged children** or **adolescents)** 3. Set T_I : Adults 0.70-1 sec; Peds based on RR to maintain a minimum ratio of 1:2 4. Select FiO_2 and PEEP (use ARDSnet grid if applicable; see next page
Flow	Square wave/constant/fixed; or Variable/decreasing ramp (potentially more physiologic); 40LPM healthy, 60LPM ARDS
I:E	• I:E of 1:2 or 1:3 is best for most patients; Normal Ti ~ 1-1.5s in non ARDS patients; Consider Ti 0.7-1 for ARDS • I:E of 1:1 or >1:1 associated with PEEPi, decreased cardiac output (CO) and oxygen delivery • Process for setting I:E may vary by ventilator make; commonly by changing Ti, inspiratory flow and flow pattern
Pros	Guaranteed MV regardless of changing respiratory system mechanics; precise control of V_T to limit volutrauma
Cons	Will overcome high resistance or compliance to deliver set V_T (must set pressure limit & alarm); breath stacking (i.e. next breath delivered before exhalation of prior breath); fixed flow and T_I can increase asynchrony when V_T & flow demand > vent settings
Breath Initiation	Control: Time trigger (60s/set RR): fixed VE Assist: Pt effort triggers full breath at set T_I, V_T, and flow rate
If No Patient Trigger	Delivers full set V_T at set rate (i.e. guaranteed VE)
Breath Termination	**Time cycled =** breath ends at set T_I; alarms if V_T not achieved; flow is set, breath ends once V_T delivered **Pressure cycled =** safety mechanism; breath termination by clinician set high-pressure limit (10-15cmH20>avg PIP); "pop-off"
Notes	• Inspiratory pause (~0.3s) can be built into each breath, will increase mean airway pressure; can measure Pplat • Alarms: high pressure 5-10 > PIP, VE 50% above+below actual • Trigger: 2-5 Lpm for flow; -2 cm H_2O for pressure



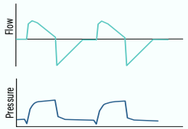
Pressure Control

Other Names	AC-PC; Assist Control Pressure Control; ~CMV - PC
Controlled Variables	**RR, Pinsp (or PC level),** PEEP, FiO_2, Flow trigger, Rise time, I:E (set directly or by Inspiratory time, T_I)
Initial Settings Adult & Pediatric (More details on next card)	1. Set inspiratory pressure (Pinsp) at 8-20cm H_2O, or set equal to previous Pdr, Pplt or ~1/2 of PIP if transitioning from VC (goal 6-8 m:/Kg PBW 2. Set RR: **Adults:** set at pt's most recent RR (do not exceed 35); **Peds:** set at most recent RR (do not exceed 60 bpm in **infants,** 40 bpm in **toddlers/preschoolers,** 35 bpm in **school-aged** children or **adolescents)** 3. Set T_I : Adults 0.70-0.85 sec; Peds based on RR to maintain a minimum ratio of 1:2 4. Select FiO_2 & PEEP (use ARDSnet grid if applicable; see next page
Flow	• Variable/decreasing ramp (potentially more physiologic) • Peak Flow determined by: 1) Pinsp level, 2) R, 3) T_I (shorter = more flow), 4) Pressure rise time (↓ Rise time → ↑ Peak flow), 5. Pt effort (↑ Effort → ↑ Peak flow)
I:E	• I:E of 1:2 or 1:3 is best for most patients; Ti 0.7-1s for ARDS • I:E 1:1 or >1:1 associated with PEEPi, decreased CO & O_2 delivery Determined by set T_I and RR (Volume and flow variable)
Pros	• Avoids high PIPs • Variable flow (↑ pt effort causes ↑flow to maintain constant airway pressure = potentially better synchrony: ↑ pt effort → ↑ flow and ↑ V_T) • "Automated/active expiratory valves" (transiently opens expiratory valve to vent off pressure with coughing, asynchrony); ↑ comfort and ↓ barotrauma risk
Cons	V_T and MV not guaranteed; V_T determined by C and R (might be bigger or smaller than is optimal)
Breath Initiation	Control: Time trigger - (60s/set RR) Assist: Pt trigger delivers Pinsp for inspiratory time cycle
If No Patient Trigger	Delivers Pinsp at set rate and T_I
Breath Termination	Time cycled = I:E or T_I set, breath ends at set time
Notes	• Pplat is the set inspiratory pressure • Alarms: high pressure 5-10 > PIP, VE 50% above+below actual • Trigger: 2-5 Lpm for flow; -2 cm H_2O for pressure • Unlike in VC, in PC the ventilator cannot compensate for volume lost to circuit compliance (i.e. V_T delivered may be less than V_T measured and my be significant especially in pediatrics)



Pressure Support

Other Names	PS; PSV; Spontaneous
Controlled Variables	**Pinsp,** PEEP, FiO_2, Flow trigger, Rise time
Initial Setting Adult & Pediatric (More details on next card)	Use for Spontaneous Breathing Trial (SBT): 1. Set Pinsp 5-10 cm H_2O accounting for ETT size (3.0/3.5mm = 10 cm H_2O; 4.0/4.5mm = 8 cm H_2O; ≥5mm = 5 cm H_2O 2. Set PEEP 5-8 cm H_2O 3. FiO_2 ≤0.40 (Peds) or ≤0.50 (Adults) per SBT initiation criteria
Flow	• Decreasing ramp (potentially more physiologic) • Determined by 1) PS level; 2) Airway resistance (R_{aw}); 3), Rise time (↑ Rise time --> ↓ Peak flow) and 4) Pt effort
I:E	Determined by patient effort and flow termination ("E_{sens}" - see below "Breath Termination")
Pros	Synchrony: allows pt to determine peak flow, V_T, and T_I
Cons	• No guaranteed MV; V_T determined by pt (big or small); high • PS and/or low E_{sens} in COPD can incr air-trapping asynchrony; muscle weakness/fatigue: ↓ effort or ability to sustain effort --> hypoventilation, ↑ fatigue
Breath Initiation	Pt flow or pressure triggered; Flow (3-5LPM) more sensitive than pressure trigger (~2cm H_2O)
If No Patient Trigger	Apnea (Most vents will have backup rate; all have alarm)
Breath Termination	Flow cycled: Delivers Pinsp until flow drops to predetermined % of initial peak flow **~Esens** (Standard setting ~25%; ~40-50% if obstructive pulmonary disease to prevent air trapping)
Notes	PS mode is not necessarily equivalent to a spontaneous breathing trial (SBT); Consider additional 3-5 cm H_2O of delta pressure if HME used



Dual (Control) Mode

Other Names & Function	• Pressure regulated volume control (PRVC); VC+, AutoFlow • ~PC with a target V_T & variable Pinsp (Δ1-3cmH2O per breath) to meet goal V_T despite changing C and R;
Pros	• ↓ likelihood of hypo/hyperventilation associated with PC. • If R or C changes, Pinsp automatically adjusts to keep target V_T • Active expiratory valve (unlike AC-VC) promotes synchrony
Cons	• C & R can change significantly without notification • Vent can't discern if V_T>target is due to ↑ pt effort or ↑ C; vent response to both = ↓ Pinsp; Can lead to closed-loop "runaway" (↓ Pinsp--> ↑ Pt Effort--> ↓ Pinsp)= ↑ Pt work; must carefully set alarms

Respiratory Care, Setup, & Monitoring

Ventilator Setup (prior to connecting patients)
- Inspect all equipment for **cleanliness** or damage
- Review circuit orientation, filters, & heat & humidification system
- Ensure gas supply connected
- Perform machine self-test with new patient and per manufacture (ensure leak test included)
- Confirm initial settings and alarms

Ventilator Performance
- Perform Full Status Check q4h: (PIP, Pplat, V_T, FiO_2, auto-PEEP, Alarms, SpO_2, $ETCO_2$ in addition to routine ICU monitoring)
- Evaluate vent & patient within ~1h of ventilator settings changes
- Wipe down ventilator with approved disinfection qShift

Pulmonary, Endotracheal Tube & Circuit Hygiene
- Check cuff pressure and auscultate q12h to avoid over-inflation/leak (<25 cmH_2O); consider 'minimal occluding volume' in peds
- Check inflation of pilot balloon to ensure it remains inflated
- Reposition & secure endotracheal tube with skin checks q12h
- Check ventilator circuit qShift for moisture accumulation (drainage); change circuit only if damaged or gross contamination **(VAP PPx)**
- Head of bed 30 degrees elevated for pneumonia prophylaxis **(VAP PPx)**
- Oral hygiene with mouthwash & suctioning TID **(VAP PPx)**
- Consider continuous subglottic suctioning or q12h oropharyngeal suctioning **(VAP PPx)**

Filters
- All external filters should be inspected ≥daily (and after nebs)
- Replace viral filters as frequently as supplies allow in accord with the manufacturer's recommendations or if damaged/soiled (may last >1 week)
- For turbine & compressor ventilators, external inlet filters & fan filters must be cleaned at least monthly. For ventilators that allow, bacterial/viral filters should be placed proximal to external intake filters
- Minimize instrumental/filter deadspace

Heat & Humidification
- Active system: must use distilled or sterile water (~>500mL daily) to avoid infectious risk and device damage; can be made on site or purchased; check H2O supply q12-24h
- Passive heat moisture exchanger (HME): Only some HME include pathogen filter capability; Many manufacturers suggest change q24h, but studies show that an unsoiled HME in some circumstances can be used for 3-7 days. Nebs decrease lifespan (and must be given via bypass or with HME removed from circuit). Monitor for signs of an increased resistance (e.g. increase in PIP but no change in Pplat, or a prolonged exp flow). Ensure at least 28-30 mgH20/L efficiency

Respiratory Specific Monitoring
- Continuous pulse oximetry, if unable then spot check as frequently as possible
- Continuous capnography, if unable then spot check as frequently as possible, especially after major ventilator settings changes
- Auscultation performed routinely with checks
- Skin/Mucosal Assessments qShift

Contingency Planning
- Ensure manual (i.e. bag valve resuscitator) ventilation device is operational and at beside along with a face mask and PEEP valve

Lung-Protective Ventilation (LPV)

When to Use LPV?

All ARDS patients and most intubated non-ARDS patients will benefit from LPV, though there are some instances where departures from LPV are justified (i.e. mechanical ventilation ≤24h).

ARDS Berlin Definition for Adult ARDS with Kigali Modification
1) Acute (within 1 week of new symptoms or insult)
2) Bilateral opacities on CXR or Chest CT or chest US
3) P:F ≤300 or S:F <315 with or without ≥5 cmH_2O PEEP
4) Not fully explained by cardiac failure or fluid overload on exam

Pediatric ARDS (pARDS) Definition
1) Acute (within 1 week of new symptoms or insult)
2) Infiltrate(s) on chest imaging consistent with acute lung disease
3) Non-Invasive Ventilation: P:F ≤300 or S:F ≤264 with CPAP ≤5 cmH_2O Invasive Ventilation: Oxygen Index (OI) ≥4 or Oxygen Saturation Index (OSI) ≥5
4) Not fully explained by cardiac failure or fluid overload on exam; exclude perinatal related lung disease

Acute Respiratory Distress Syndrome (ARDS)

Severity Grading of ARDS *(Correct for altitude)*

	Adult: P:F ($PaO2 \div FiO2$)	Peds: OI & OSI
Mild	P:F 200-300, ~27% mortality	OI 4-7.9; OSI 5-7.4
Moderate	P:F 100-200, ~32% mortality	OI 8-15.9; OSI 7.5-12.2
Severe	PF: <100, ~45% mortality	OI>16; OSI>12.3

If P:F <150 and worsening ARDS, consider adjunctive therapies

Tidal Volume (V_T)

(Goal 4-6 mL/Kg PBW)
- **Measure height & calculate predicted body weight** (PBW) **(See table)**
- **Set initial V_T 6 mL/kg PBW**(AC-VC)
- **Check V_T** at least every 4h (PC or if weaning PS mode)
- **Titrate V_T** by pressure goals & pH (below)
- If pH < 7.15 consider increase V_T toward 8mL/kg regardless of Pplat

Pressures

(Adults Goals: Pplat<30cmH_2O and Pdr <15 cmH_2O)

(Pediatric Goal: Pplat<28cmH_2O)

Check Pplat (0.5s inspiratory pause) & Pdr (deltaP=Vt/C_{RS} = Pplat-PEEP) ~q4-6h and after each change in PEEP or V_T
- If adult Pplat >30 cmH_2O (>28 Pediatrics), optimize sedation (+paralysis) and decreasing V_T by 0.5-1 cc/kg toward ~4 mL/kg
- If Pplat <30 cmH_2O and severe patient-ventilator dyssynchrony that cannot be addressed pharmacologically, consider increase V_T in 1 mL/kg steps up to 8 mL/kg
- If Pplat <25 cm H_2O and V_T <6 mL/kg, increase V_T to 6 mL/kg
- If PEEP ≥20 then use Pdr goal <15 (rather than Pplat goal)

Respiratory Rate (RR) & Inspiratory Time (Ti)

(Goal based on pH)

Set RR at ~pre-intubation RR don't exceed ~35 breaths/minute (Adults)

Set Ti 0.70-0.85 sec (may be longer if low RR) (avoid Ti <0.70 sec)
- When changing V_T, adjust RR to keep target VE by goal pH (~8-12 L/min in acute ARDS)
- Consider lower RR if evidence of obstructive ventilatory defect
- Increase RR if pH <7.30 and decrease RR if pH >7.45
- Keep duration of inspiration ≤ expiration

PEEP & FiO2

(Goal to minimize)
- **Start at 5 cmH_2O PEEP for 2min, if stable hemodynamics, then**
- **Select one of the following PEEP / FiO_2 titration strategies for goal** PaO_2 55-80 mmHg or SpO_2 88-95% (In ARDS, PEEP usually ~10-14 cmH_2O).
- When ↑ PEEP, if Pplat ↑ more than Δ PEEP, think over-distension

Lower PEEP/higher FiO_2 Strategy (*Default - May consider if low Pdr or pediatrics)

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	12	14	14	14	16	18		18-24

Higher PEEP/lower FiO_2 Strategy (May consider if Pa02/FiO2 is <100, high Pdr, or BMI>40)

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5 - 0.8	0.8	0.9	1.0	1.0
PEEP	5	8	10	12	14	16	16	18	20	22	22	22	24

Adjunctive Therapies for ARDS Hypoxemia

Fluid Management
- **Concentrate IV medications and consider diuresis** once hemodynamically tolerated with goal of euvolemia
- **FACTT Trial** of conservative vs. liberal fluid strategy showed conservative fluid strategy improved oxygenation, more ventilator-free & ICU-free days, no increased shock. However, no mortality benefit.

Paralysis
- **Check adequate sedation, then consider paralysis** no longer than needed
- Choice of agent (each with pros & cons, may vary by setting): cisatracurium, atracurium, rocuronium, pancuronium, or vecuronium
- Monitor degree of paralysis with serial train-of-four (TOF) & wean as able
- **ACURASYS Trial** showed mortality benefit; **ROSE Trial** did not
- Short term paralysis eliminates work of breathing and can be helpful to accurately assess respiratory mechanics & asynchronies associated w/ ARDS

Prone Positioning
- **Prone patient for ~16h at a time,** continue proning until P:F >150 with PEEP remaining <10 cmH_2O while patient is supine for >4h
- **Alternate with supine positioning** which allows for patient care
- **Do not need special bed; manually proning requires a team**
- **If unable to prone,** could put less diseased lung down to improve V/Q match
- **PROSEVA Trial** showed mortality benefit

Pulmonary Vasodilator Therapy
- No data demonstrate mortality benefit with pulmonary vasodilators
- **Inhaled Prostacyclin Initial Dose:** 50 ng/kg/min PBW (range 10-50 ng/kg/min); should be weaned (10 ng/kg/min increments q30min; once at 5ppm consider wean by 1ppm) to avoid hemodynamic compromise
- **Inhaled Nitric Oxide (iNO) Initial Dose:** ~20ppm; should be weaned (5 ppm increments q30min) to avoid potential hemodynamic compromise
- **Caution** if reduced left ventricular function, pulmonary hemorrhage, platelets <50, or anticoagulation

Additional LPV Reference Calculations

Predicted Body Weight (PBW) (kg)

Males = 50 + 2.3 [height (inches) - 60]
Females = 45.5 + 2.3 [height (inches) -60]

Scan for PBW Calculator

Height	PBW f/m	4mL/Kg f/m	5mL/Kg f/m	6mL/Kg f/m	7mL/Kg f/m	8mL/Kg f/m
58" (147cm)	40.9/45.4 kg	164/182	205/227	245/272	286/318	327/363
60" (152cm)	45.5/50 kg	182/200	228/250	273/300	319/350	364/400
62" (157cm)	50.1/54.6 kg	200/218	251/273	301/328	351/382	401/437
64" (163cm)	54.7/59.2 kg	219/237	274/296	328/355	383/414	438/474
66" (168cm)	59.3/63.8 kg	237/255	297/319	356/383	415/447	474/510
68" (173cm)	63.9/68.4 kg	256/274	320/342	383/410	447/479	511/547
70" (178cm)	68.5/73 kg	274/292	343/365	411/438	480/511	548/584

Imputed Values for P:F Ratio
- Use when blood gas analysis unavailable **(Link to source data)**

Scan for Imputed P:F Calculator

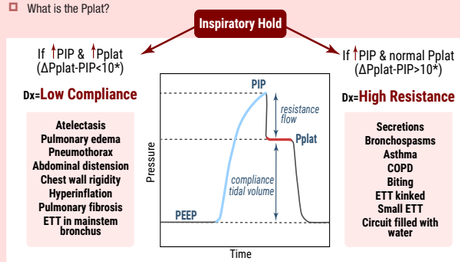
SpO_2 Values Corresponding to P:F ≤150:

Measured SpO_2	Imputed PaO_2	FiO_2	Imputed P:F
96%	82 mmHg	≥0.6	≤137
95%	76 mmHg	≥0.5	≤152
94%	71 mmHg	≥0.5	≤142
93%	67 mmHg	≥0.5	≤134
92%	64 mmHg	≥0.5	≤128
91%	61 mmHg	≥0.4	≤153
90%	59 mmHg	≥0.4	≤148
<89%	≤57 mmHg	≥0.4	≤150

High Pressures, Desaturations & Dyssynchrony

General Considerations
- Is the ventilator set to FiO_2 100% while you troubleshoot?
- Is the patient hemodynamically unstable? If so, consider pressors & urgent evaluation for pneumothorax or severe auto-PEEP.
- Is the ventilator circuit connected & set correctly?
- Are breath sounds bilateral? If unilateral, consider mainstem ETT, lobar collapse, atelectasis, and pneumothorax.

High Pressures
- Is the patient agitated or asynchronous?
- Can a suction catheter pass easily through the endotracheal tube? If no, consider kinked tube, biting/bite block, secretions/suction, or replace ETT.
- What is the Pplat?



Troubleshooting low compliance: Decrease V_T & evaluate for breath stacking (auto-PEEP). Consider ↓ PEEP or adjunct therapies for hypoxemia if decrease in PEEP causes desaturations.

Troubleshooting high resistance: Work outside (machine) to inside (alveoli); circuit problem, ETT kink/occlusion/biting, ETT obstructed/mainstem, large airway obstruction (mucous plug), small/medium airway obstruction (bronchospasm); auscultation & passing a suction catheter can quickly eliminate many of these.

Desaturations
- Is the endotracheal tube in good position? (consider CXR)
- Is the pulse oximetry waveform good quality?
- Is there acute hypotension? Evaluate for tension pneumothorax, air trapping and pulmonary embolism
- Is the source of oxygen faulty or is there an air leak? Check each connection/element sequentially from source of oxygen to the patient.
- Are there concomitant pressure elevations? If so, see "High Pressures" (next column)
- Is P:F <150 in setting of worsening ARDS? If so, consider adjunct therapies (above).
- Are there signs of infection? Consider ventilator-associated pneumonia.

Patient-Ventilator Dyssynchrony
- Detect signs of dyssynchrony: coughing, paradoxical breathing, ventilator alarms (low tidal volumes or high pressures), breath stacking.
- Treat underlying causes: 1) Ineffective triggering (patient or ventilator); 2) Inappropriate triggering (patient inspires while ventilator expires); 3) Auto-triggering (non-respiratory muscle movement triggers ventilator); 4) Flow dyssynchrony (too fast or too slow)

General Approach
- Treat pain or anxiety if present
- If ineffective ventilator triggering change trigger sensitivity, decrease VT or pressure
- Increase V_T to 8 mL/kg and increase flow rate if pressures allow. Consider change to decelerating flow delivery if setting available.
- If still dyssynchronous, paralyze patient (and sedate patient to RASS goal -5)

Discomfort & Delirium

Discomfort (pain, agitation, anxiety) & Delirium
- Ensure appropriate analgesia & sedation to minimize ICU/IMV duration & risk of long-term neuropsychiatric impact.
- **Reassess every ≤4 hours using a standardized scale**
  - Goal RASS -4 to 0 in intubated patients
  - If RASS -4 tor -5 consider lightening sedation unless patient is paralyzed or dyssynchronous with ventilator.
  - Target RASS -5 for paralyzed patients. Never paralyze without sedation
- Perform Daily Sedation Interruptions (DSIs) in non-paralyzed patients to reassess sedation & analgesia needs, which can guide weaning these medications.

Richmond Agitation Sedation Scale (RASS)

Delirium: Prevention & treatment of delirium reduces mortality and ICU/IMV duration
- Screen every 12h using standardized tool (i.e. CAM-ICU)
- Treat delirium by addressing underlying causes (pain, agitation, anxiety, or physiologic derangements

Confusion Assessment Method for the ICU (CAM-ICU)

Ventilator Weaning & Extubation

SBT Initiation Criteria (& Considerations)
- **Patient likely to trigger ventilator and FiO_2 ≤ 0.50 adults (≤ 0.40 for pediatrics) and PEEP ≤8**
- pH > 7.30. VE < 15 L/min
- ~MAP > 60 mmHg (minimal pressors)
- ICP: non-labile and < 20 mmHg w/ CPP > 60 mmHg
- No MI in previous ~48hr

Weaning Strategies
- Once daily SBT PS delta 5-7 cmH_2O if ETT size > 5 (8 cmH_2O if ETT 4-4.5; 10 cmH_2O if ETT 3-3.5) over PEEP 5-8 cmH_2O (2nd daily trial ok if failure sedation-related or due to transient issue)(Consider additional 3-5 cmH_2O of delta pressure if HME used)
- SBT x 30min ~probably as good as SBT x 2hr if <48h intubated
- SBT x 2hr better predictor if intubated >48h
- If adult with cardiogenic pulmonary edema risk: Consider 15min T-piece (i.e. d/c PS & PEEP)
- RSBI (rapid Shallow Breathing Index) = f/V_T is unreliable; <80 goal for extubation; sensitive, not specific (if > 105, good predictor of failure)
- Daily sedation interruption = faster extubation, shorter LOS

Extubation Criteria
- Have you fixed the original problem and **no upcoming procedures?**
- Adequate **oxygenation?** (PaO_2 > ~60 on PEEP< 8 cmH_2O, FiO_2 <0.50)
- Adequate **ventilation** without excessive **work of breathing?** ($\Delta PaCO_2$ ↑ of < 10 mmHg with remaining pH > 7.30 during SBT)
- **Secretions?** (assess cough strength, suction frequency & secretion volume)
- **Airway protection?** (assess gag, spontaneous cough and GCS)
  - Assess **risk of post-extubation airway obstruction:**
  - Consider cuff leak test if: intubation >6d, trauma, multiple intubations, prolonged prone, flat, volume overload, head/neck trauma, among others

  Cuff Leak Test: 1. pt must be sedated (interaction with vent = incr PIP= incr leak = false reassurance); **2.** Suction oropharynx; **3.** Initiate AC-VC V_T 8 mL/kg, RR 12, Ti: 1.5sec, Flow 50 LPM; **4.** Measure expired V_T; **5.** Deflate cuff and wait 6 breaths; **6.** Measure expired V_T expired V_T (goal is ↓ by >110mL in measure expired V_T); **7.** Reinflate cuff
  - Decrease aspiration risk by holding tube feeds for safe interval (~6-8h)
  - Extubation criteria/goals for neuro patients may be different (e.g. visual tracking, swallowing, GCS>10, <40yo)
- **Hemodynamics -** re-intubation of an unstable patient can be lethal