Common Problem In Ventilatory Patients
Algorithmic Approach

Cleveland school of medicine
ICU department
Initiation of M.V

Indication?
- Severe respiratory distress
- Altered mental status
- Severe respiratory acidosis
- Refractory hypoxemia

Intubate
Start assist control
Rate 12-14/min
TV 8-10 cc/kg
FiO₂ 100%
PEEP 5 cm H₂O

Assess clinically
ABG in 10-15 min

pH and PaCO₂
- Normal or close to baseline
  - Maintain present TV and respiratory rate
- Respiratory alkalosis
  - Decrease TV, decrease respiratory rate
  - Sedate/paralyze
  - Control pain
- Respiratory acidosis
  - Increase TV
  - Increase respiratory rate

PaO₂
- Adequate
  - Decrease FiO₂ by 10% at a time; follow SpO₂, think about early weaning
- Inadequate
  1. Increase PEEP
  2. Consider barotrauma
  3. Treat Underlying disease
  4. Sedate/paralyze
  5. Correct anemia
  6. Optimize cardiac output
  7. Nurse pt with healthy side dependent
  8. Consider pressure control ventilation with inverse I:E ratio
  9. Consider ECMO
Weaning protocol

- Minute volume < 5 lpm
- Minute volume ≥ 2 lpm above initial spontaneous min. volume
- An ETCO₂ ≥ to 10 mmHg above baseline
- r/rVt > 105
- SpO₂ < 90%

Should weaning begin? (Physician ordered)

1. Yes
2. Is the patient able to maintain minute volume spontaneously with a r/rVt ratio < 105 for greater than 45 min without support?
3a. Begin weaning using continuous flow.
3. Begin wean using pressure support (P.S.) to maintain r/rVt < 105 while maintaining baseline minute ventilation

4. During the first hour have any stop points been reached?
5. Yes
5a. Rest on ventilator. Proceed with weaning schedule bid at step 6a.
4a. No

5. No
6. Continue to monitor and decrease P.S. q 30 minutes by decrements of 3 cm H₂O.

6a. Have any stop points been reached during the ensuing hour?

6b. Yes
7a. Resume weaning, Have stop points been met during this weaning period?
6. No
7a. Increase weaning period by one hour bid. Continue to monitor for stop points.
7a. No

Return to ventilator and reassess next shift
Weaning protocol

1. Have any stop points been reached during the ensuing hour?
   - Yes: Increase P.S. until stop point(s) are no longer exceeded
   - No: Continue at present level of P.S. and monitor for stop points. Continue at step 4 the following am.

2. Have any stop points been met during the succeeding hour?
   - Yes: Increase weaning period by one hour bid. Continue to monitor for stop points.
   - No: Rest on ventilator until next scheduled weaning period.

3. Have stop points been met during this weaning period?
   - Yes: Resume weaning.
   - No: Continue to monitor for stop points.
Hypoxia approach in non-intubated ICU patients

**Work-up:**
- History and P/E
- ABG
- Chest X-ray

**Differential Diagnosis:** See Next Page

- Continue oxygen
- Treat underlying cause
- Close monitoring

**Hypoxia**

- Start supplemental oxygen
- Follow Pulse Oximetry

- Titrate FIO₂ to Keep SpO₂ > 90%

- SpO₂ > 90% with supplemental O₂

- Yes

- Altered mental status
  - Hemodynamically unstable
  - Intubation
  - Mechanical Ventilation
  - No Change
    - Worsened or unable to tolerate

- Normal mental status
  - Hemodynamically stable
  - Consider NIPPV eg BIPAP
  - Improved
Hypoxia

Start supplemental oxygen

Follow Pulse Oximetry

Titrated FIO₂ to Keep SpO₂ > 90%

Yes

SpO₂ > 90% with supplemental O₂

No

Altered mental status
Hemodynamically unstable

Intubation
Mechanical Ventilation

No Change
Worsened or unable to tolerate

Normal mental status
Hemodynamically stable

Consider NIPPV eg BIPAP

Improved

Work-up:
- History and P/E
- ABG
- Chest X-ray

Differential Diagnosis:
See Next Page

- Continue oxygen
- Treat underlying cause
- Close monitoring
Hypoxia approach in general ward

Hypoxia
  -------
     /     \
    /       \   
--- Increased --- Normal
     /         \
    /           \-- Respiratory Acidosis
     /               \
--- PaCO₂ ---
     /         \-- Normal or Low
    /           \   
--- Increased ---
     /         \   
    /           \-- Type II Respiratory Failure
     /               \
--- COPD Exacerbation Status Asthmaticus ---
     /               \
--- Consider PE ---
     /               \
--- Abnormal ---
     /               \
--- Focal Infiltrates ---
     /               \
--- Diffuse Infiltrates ---
     /               \
--- Pneumonia Atelectasis ---
     /               \
--- Clinical Features Hemodynamic Monitoring ---
     /               \
--- PAOP < 16 CI Normal ---
     /               \
--- Cardiogenic Pulmonary Edema ---

PAO₂ = (PATM - PH₂O) FIO₂ - PaCO₂/R
PATM = 760; PH₂O = 47; R = 0.8
PA-aO₂ = PAO₂ - PaO₂
Normal PA-aO₂ = 5 to 10 mm Hg for FIO₂ 0.21 and 100 mm Hg for FIO₂ of 1.0
Correction of PA-aO₂ and PaO₂ for age:
Normal PA-aO₂ for age = \frac{[\text{Age (yrs)} + 4]}{4}
Normal PaO₂ for age = 100 - 0.3 (Age [yrs])
Acid base disorder in brief

Acidosis Algorithm (Low pH) → Normal → Decreased PaCO₂ → Normal HCO₃ → Metabolic Acidosis and/or Respiratory Alkalosis

Alkalosis Algorithm (High pH) → Normal → Elevated PaCO₂ → Normal HCO₃ → Normal Acid-Base Balance

Alkalosis Algorithm (High pH) → Normal → Elevated PaCO₂ → Elevated HCO₃ → Respiratory Acidosis and/or Metabolic Alkalosis

Normal pH: 7.35-7.45
Acidemia: pH < 7.35
Alkalemia: pH > 7.45
Normal PaCO₂: 35-45 mm Hg
Normal HCO₃: 22-26 meq/L
Anion Gap: Na⁺ - (Cl⁻ + HCO₃⁻)
Normal Anion Gap: 8-12
Excess AG = Observed AG - Normal AG
Delta HCO₃ = Normal HCO₃ - Measured HCO₃
Acid base disorder in brief

Diagnosis of Triple Acid-Base Disorders:

Rule 1: Triple acid-base disorders involve metabolic acidosis and metabolic alkalosis with one primary respiratory disorder. Respiratory acidosis and respiratory alkalosis cannot co-exist.

Rule 2: For high anion gap acidosis, the serum $\text{HCO}_3^-$ will fall by 1 meq/L for each meq increase in anion gap. This relationship helps make diagnosis of mixed metabolic acidosis and alkalosis:

- Calculate Delta Anion gap
- Calculate Delta $\text{HCO}_3^-$

If Excess AG is $>$ Delta $\text{HCO}_3^-$, Patient has superimposed metabolic alkalosis in addition to primary high AG metabolic acidosis.

If Excess AG is $<$ Delta $\text{HCO}_3^-$, suspect a combined high AG acidosis plus normal AG acidosis.

Rule 3: If AG is $>$ 35, suspect a combined metabolic acidosis plus metabolic alkalosis.

Rule 4: In a patient with metabolic acidosis, if excess AG + Measure $\text{HCO}_3^-$ is $>$ 30, there is underlying metabolic alkalosis; if $<$ 23, there is associated non AG acidosis.
DDX of Low PH

Low pH

HCO₃ - Low

PaCO₂ - High

HCO₃ - High

Metabolic Acidosis

Increase in HCO₃ appropriate for increase in PaCO₂

Yes

Decrease in HCO₃ is < expected

Increase in PaCO₂ is > expected

Respiratory Acidosis

Metabolic Acidosis + Respiratory Acidosis

Metabolic Acidosis + Respiratory Alkalosis

Compensation for Metabolic Acidosis

For each meq/L decrease in HCO₃, PaCO₂ decreases by 1.2
Expected PaCO₂ = 1.5 x HCO₃ + 8 (+/- 2)
PaCO₂ = Last 2 digits of pH

Compensation for Respiratory Acidosis

Acute: For every 10 mmHg increase in PaCO₂, HCO₃ increases by 1 meq/L
Chronic: For every 10 mmHg increase in PaCO₂, HCO₃ increase by 3.5 meq/L
DDx of high PH

High pH

- Elevated HCO₃
- Low PaCO₂

Metabolic Alkalosis

- Increase in PaCO₂ appropriate for decrease in HCO₃

- Yes: Increase in PaCO₂ is > expected
  - Metabolic Alkalosis
  - Metabolic Alkalosis + Respiratory Acidosis

- No: Decrease in HCO₃ is < expected
  - Respiratory Alkalosis
  - Respiratory Alkalosis + Metabolic Acidosis

Respiratory Alkalosis

- Decrease in HCO₃ appropriate for decrease in PaCO₂

- Yes: Decrease in HCO₃ is > expected
  - Respiratory Alkalosis
  - Respiratory Alkalosis + Metabolic Acidosis

- No: Decrease in HCO₃ is < expected
  - Metabolic Alkalosis
  - Metabolic Alkalosis + Respiratory Acidosis

Compensation for Metabolic Alkalosis

For each meq/L increase in HCO₃, PaCO₂ increases by 0.6 mm Hg

Compensation for Respiratory Alkalosis

Acute: For every 10 mm decrease in PaCO₂, HCO₃ decreases by 2 meq/L

Chronic: For every 10 mm decrease in PaCO₂, HCO₃ decrease by 4-5 meq/L
Approach to acidosis in ICU

History & Physical Exam
Consider diabetes mellitus, renal failure, shock and poisons.

Investigations:
- ABG
- Electrolytes
- Blood glucose
- Serum ketones
- BUN/Creatinine
- Serum lactic acid
- Toxicology screen

Anion gap acidosis
Ketoacidosis
Uremia
Salicylates
Spirits (Alcohol)
Methanol
Aldehydes
Unknown toxins
Lactic acidosis

Non-anion gap acidosis
Diarrhea
Renal tubular acidosis
Uretero-sigmoidostomy
TPN
Acetazolamide

Treat underlying cause and consider bicarbonate if pH < 7.2

Anion gap calculation
\[ \text{Na}^+ - (\text{HCO}_3^- + \text{Cl}^-) \]
Normal = 12 +/- 4
Tube feeding in ICU

1. Tube feed all intubated patients first day of admission*
   Keep HOB at 30 degrees

2. Insert small bore feeding tube; confirm placement by KUB

3. Use NG tube if unable to place feeding tube properly

4. Start 25 cc/h full strength 1 Kcal/cc formula

5. Advance by 25 cc/h every 12 hours

6. Consult MIC dietician for goal rate, questions, and problems.

7. Start 25 cc/h 1/2 strength hypertonic formula

8. Advance to full strength in 12 hours

9. Advance by 25 cc/h every 12 hours
* Do not tube feed patients having GI bleeds, GI obstruction, or severe diarrhea (> 1 liter of liquid stool), acute pancreatitis, or having severe abdominal distention.

**Nutrition Care of the MICU Patient**

**Calories: Harris-Benedict Equation**

**Men:** \( BEE = 66.5 + (13.8 \times \text{wt (kg)}) + (5 \times \text{ht. (cm)}) - 6.8 \times \text{age (years)} \)

**Women:** \( BEE = 65.5 + (9.6 \times \text{wt (kg)}) + (1.8 \times \text{ht (cm)}) - (4.7 \times \text{age (years)}) \)

**Total Energy Expenditure (TEE) = BEE \times 1.2 \times \text{stress factor}**

**Stress Factors:**
- none: 1.0 - 1.2
- surgery: 1.14 - 1.37
- infection: 1.2 - 1.5
- fever: 1.4 - 1.5

**Protein:**
- 1 gm nitrogen/150 Kcal
  - (1 gm. nitrogen = 6.25 gm protein)

**Nitrogen balance study:** order Urinary Urea Nitrogen every 2 weeks

**Nitrogen balance = nitrogen intake - (nitrogen output + 4)**

**Results:**
- < 2 gm = negative nitrogen balance
- > 2 gm = positive nitrogen balance

**Transferrin:** Order every Monday
Fever in ICU

History and Physical Examination
(Systems review to localize source)

**Sepsis Work-up**
- CBC and differential
- Liver function test
- Blood cultures from 2 separate sites
- Urine microscopy and culture
- Sputum microscopy and culture
- Chest radiograph
- Culture specimens from all inflamed sites

**Culture +ve**
Narrow antibiotics and repeat work-up

**Culture -ve**
Continue empiric antibiotics

**Culture -ve**
Continue antibiotics based on ‘Best Guess’

**Culture +ve**
Narrow antibiotic cover

Repeat history, physical and septic work-up. Change all lines.

Fever resolves

Febrile

**Occult infectious cause**
- Sinusitis
- Cholecystitis
- Intraabdominal abscess

**Non-infectious cause**
- Deep vein thrombosis
- Pancreatitis
- Fibroproliferative ARDS
- Drug fever
- Central fever
Hypokalemia in ICU

**Increased loss**
Check urinary spot K

**Distribution defect**
AML, Insulin excess, alkalosis, hyperglycemia, periodic paralysis, B12 therapy

**Urinary spot K < 10**
Non-renal loss
Diarrhea, biliary loss, small intestinal fistulas, laxative abuse.

**Urinary spot K > 20**
Renal loss
Check BP

**HTN**
Hyperaldosterone State

**Check plasma renin**

**HTN**
Hyperaldosterone State

**Normal BP**

**Check plasma HCO₃⁻**

**Increased**
Secondary hyperaldo

**Decreased**
Primary hyperaldo

**Decreased**
RTA 1
RTA 2

**Increased**
Check urinary Cl

**THERAPY**
Find and correct cause
Replace Mg²⁺ 2.5-3.5
Check monitor
Syp KCl po 40 meq
KCl i/v 40 meq @10 meq/hr
< 2.5
Check EKG
Syp KCl po 40-80 meq
KCI i/v 80 meq @10-15 meq/hr

< 10
Vomiting with metabolic alkalosis
Hyperaldo state

> 10
Bartters, diuretics, normotensive hyperaldo
Hyperkalemia in ICU

R/O Pseudohyperkalemia
- Hemolysis
- Leucocytosis
- Thrombocytosis

Check plasma/blood K

Excess K intake
(Urine spot K > 50 mEq/L)
- K supplements
- K penicillin
- Stored blood
- Salt substitutes

Translocation from ICF to ECF
- Acidosis
- Severe catabolism
- Rhabdomyolysis
- Tissue necrosis
- Insulin deficiency
- Mineralocorticoid deficiency (adrenal insufficiency, hyporeninemic, hypoaldosteronism)
- Periodic paralysis
- Aldosterone antagonists
- Digitalis toxicity
- Succinylcholine
- B-blockers
- Catecholamine deficiency states
- Hyperosmolarity

Decreased excretory capacity
(Urine spot K < 50 mEq/L)
- Renal failure
- Oliguria
- Renal tubular disease
- K sparing diuretics
- Hypoaldosteronism
- Cyclosporine
- ACE inhibitors
- NSAIDS

Therapy General
Treat underlying cause
Restrict exogenous K
Remove offending drugs. K > 6
- Check EKG
- CaGluconate 2 amps. I/V
- D50 1 amp./10U insulin I/V
- NaHCO₃ 1-2 amps. I/V over 5-10'
- Kayexalate 30-60 gm PO
- Lasix
- Dialysis
- Repeat K
- B agonist inhaled
Sedation in ICU

**Base Line TOF (Train of Four) Procedure**

**STEP 1:** Prior to Neuromuscular Blocker (NMB)

- a. Locate ulnar/facial nerve
- b. Dial voltage to 30 on the nerve stimulator and press TOF, increase voltage by 10 and repeat TOF until 4 noticeable twitches
  1. DO NOT EXCEED VOLTAGE OF 80; check batteries
- c. **Record the voltage needed for response on bedside chart** and use the same current every shift.

**STEP 2:** Dosage Adjustment

<table>
<thead>
<tr>
<th>TOF Response</th>
<th>Intermittent IV Push Dosing (Pancuronium, Vecuronium q2hr PRN)</th>
<th>Continuous Infusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/4-0/4</td>
<td>Maintain same dose</td>
<td>Maintain same dose</td>
</tr>
<tr>
<td>3/4-4/4</td>
<td>Give additional bolus and increase dose by 20%</td>
<td>Give bolus and increase infusion by 2 ml/hr; check TOF in 30 min</td>
</tr>
</tbody>
</table>

**STEP 3:** Frequency

<table>
<thead>
<tr>
<th>TOF: q2 hr</th>
<th>TOF: q2 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/4</td>
<td>Hold next dose and repeat TOF q1-2 hr until 1/4-2/4 then rebolus</td>
</tr>
<tr>
<td>1/4-3/4 and Clinical Response</td>
<td>Maintain same regimen and check TOF q2 hours</td>
</tr>
<tr>
<td>1/4-3/4 and NOT Clinically Controlled</td>
<td>Increase dose by 10-20% and TOF q2hr</td>
</tr>
</tbody>
</table>

**STEP 4:** **Remember:** lubricant to eyes q6 hours, close and protect eyes, DVT prophylaxis and PRAFO boots
Hypotension in ICU

- IV Normal Saline 500 ml
- Clinical Assessment
- Review Medications
- Ensure adequate IV access

Fluid resuscitation

Hypotension Resolved?

Still Hypotensive?

Assess hydration
Assess cause
Observe

Continue fluid resuscitation
Add dopamine or norepinephrine
Assess cause

Volume Problem

Assess for:
- GI Bleed
- Diarrhea
- Sepsis

- EKG
- Cardiac enzymes
- ECHO
- Swan-Ganz catheter

Pump Problem

Arrhythmia

Bradyarrhythmia
- Atropine
- Pacing

R/O Auto PEEP, pneumothorax

Tachyarrhythmia
- DC Shock
- IV antiarrhythmics

R/O MI, PE, Tamponade

EKG, cardiac enz. positive and wall motion abnormalities

Diastolic equalization of pressures, diastolic collapse of RV on Echo

VQ scan, Duplex US, RV dilation on ECHO and PA gram

MI
Tamponade
PE
Hemodynamic control in ICU

- **PAOP**
  - Low: Infuse Volume
  - Adequate: Cardiac Output
  - High: Pulmonary Edema

  - Cardiac Output
    - Low: MAP
      - Low: Dopamine
      - Borderline Low: Dobutamine
      - Normal: Vasodilators
      - Maintain Optimal PAOP
\[ DO_2 = CO \times CaO_2 : 500-700 \text{ ml/min} \]
\[ CaO_2 = (1.36 \times Hb \times SaO_2) + (PaO_2 \times 0.003) \]
\[ VO_2 = CO \times C(A-VO_2) \times 10 : 110-160 \text{ ml/min} \]
\[ C(A - VO_2) = 5 \]
\[ \text{Extraction Ratio (ER)} = \frac{VO_2}{DO_2} : 22-32\% \]
\[ \text{Mixed venous saturation} = 68-75\% \]
\[ \text{Mixed venous oxygen} : 33-53 \text{ mm Hg} \]

**Dopamine**: 5-20 mcg/kg/min  
**Dobutamine**: 5-20 mcg/kg/min  
**Norepinephrine**: 2-80 mcg/min (start at 0.5-1.0 mcg/min)  
**Epinephrine**: 1-200 mcg/min  
**Nitroglycerine**: 10-300 mcg/min (start at 10-20 mcg/min)  
**Nitroprusside**: 0.5-8.0 mcg/kg/min (start at 0.1 mcg/kg/min)

Swan Ganz Data:

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>PAOP</th>
<th>CO</th>
<th>SVR</th>
<th>( DO_2 )</th>
<th>( VO_2 )</th>
<th>( O_2ER )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhagic</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Sepsis</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
Diarrhea in ICU

1. Assess intravascular volume and replace fluids & electrolytes as appropriate.

2. Confirm true diarrhea and not fecal retention with overflow. Rectal Exam.

3. In-hospital diarrhea?
   - Yes
   - No
Iatrogenic
Mg containing laxative
Stool softeners
Chemotherapy
Radiation
Tube feeds
Sorbitol/Mannitol containing medication

Decrease Drug

Diarrhea unresolved

Look for evidence of inflammation
Fever, leucocytosis, left shift, stool WBC & RBC

Yes
No

History & Physical Exam
Travel History
H/O Ingestion
Acute vs Chronic

Diarrhea resolves

Start empiric Flagyl

Stool C. Diff toxin and culture

Positive
Negative

Continue Flagyl or PO Vancomycin

DC Flagyl Stool for c/s, ova & parasites

Positive
Negative

Rx appropriately

Infectious
Salmonella
Shigella
E. Coli (enteroinvasive)
Campylobacter
Hemorrhagic E. Coli 0157:H7
C. Diff colitis
Amoeba

HIV +ve patients also have:
Cryptosporidium
Isospora
MAI
Candida etc.

Viral
Rota Virus
Norwalk
Giardia
Toxins - E. Coli
Staph. aureus
C. Difficile

HIV +ve patients also have:
CMV
HSV
HIV
Kaposi etc.

Non-infectious
Radiation colitis
Ischemic colitis
Inflammatory bowel disease

Start empiric Flagyl & send stool for c/s, ova & parasites

Negative

Call appropriate consult

DC Flagyl
ARF in ICU

Acute renal failure in ICU

- History & Physical Review medications
- Send Urinary Electrolytes & U Osm
- Urinary Sediment
- Serum electrolytes

Assess volume status
Monitor urine output
Adjust medication doses
Avoid nephrotoxic agents

Rule out obstruction

Place IUTC Renal ultrasound

Obstruction?

- Yes
  - Post-Renal Azotemia

- No
  - Hypovolemia

Clinical Evidence
- FENa < 1
- UOsm > 500
- Few hyaline casts

- Yes
  - Pre-Renal Azotemia

- No
  - Renal Azotemia

RBC Casts
- Dysmorphic RBC
- UOsm > 500
- FENa < 1

Pigmented Granular Casts
- UOsm < 350
- FENa > 1

Urine Eosinophilia
- Skin Rash
- UOsm < 350
- FENa > 1

Clinical evidence of CHF?

- Yes
  - Hemodynamic Monitoring
  - Volume Replacement

- No
  - Glomerulonephritis
  - Acute Tubular Necrosis
  - Interstitial Nephritis

Renal Consult

Optimize cardiac output and intravascular volume.

Follow urine output, renal functions and serum electrolytes
Respiratory difficulty in ICU

Abnormal Respiratory Drive
- Tachypnea
- Hypoxemia
- Respiratory acidosis

Decreased Peak Pressure
- Decreased
- 1. Air leak (e.g. disconnected tubes, cuff leak)
- 2. Hyperventilation (e.g. pain, anxiety, agitation)

Increased Plateau Pressure
- Increased
- Unchanged
- 1. Pulmonary Thromboembolism
- 2. Extrathoracic Process

Decreased Compliance
- 1. Abdominal Distention (e.g. gas from positive pressure ventilation or pneumoperitoneum, ascitic fluid, peritoneal dialysis)
- 2. Atelectasis (e.g. diffuse microatelectasis, lobar collapse)
- 3. Large pleural effusions
- 4. Pneumothorax
- 5. Stiff lung (e.g. acute respiratory distress syndrome, cardiogenic pulmonary edema, fluid overload, pneumonia)
- 6. Severe Hyperinflation (e.g. auto-PEEP in obstructive lung disease)

Increased Airway Resistance
- 1. Acute Bronchospasm
- 2. Aspiration of oropharyngeal or gastric contents
- 3. Endotracheal tube obstruction (e.g. kinking or clenching teeth)
- 4. Obstruction from retained airway secretions (e.g. mucus plugging)