

2018

SUNY Upstate Medical University

ICU SURVIVAL GUIDE

Ravi Doobay, Subrat Khanal, Lauren Krowl, Ryan
Dean, Prathik Krishnan, Hassan Al-Khalisy Brian
Pratt, Ioana Amzuta, Carlos Martinez-Balzano,
Amit S. Dhamoon

The ICU can be an intimidating and stressful environment. This manual is intended to help support medical students, interns, and residents working in the ICU.

Please be mindful that this manual is a *guide* for care in the ICU. Clinical treatment decisions are variable and nuanced depending on patient, nursing, and attending factors.

Table of Contents:

Day MICU Expectations	Page 4
Night MICU Expectations	Page 5
Sepsis	Page 6
Respiratory Failure	Page 12
Mechanical Ventilation	Page 14
Liberation from Mechanical Ventilation	Page 15
COPD	Page 17
Asthma	Page 19
GI Bleeding	Page 20
DKA/HHS	Page 23
Acid Base Disorders	Page 24
Sedation	Page 25
Delirium	Page 29
ICU Drips	Page 32

Day MICU Expectations:

- When a service asks for a consultation, confirm that an EPIC consult order is placed.
- Consults should be seen within 30 minutes.
- Consults should be presented to either the Fellow or Attending.
- If a patient is readmitted to the ICU, it is considered a bounce back if the same Attending or Fellow is on service.
- If a patient is admitted to the ICU, an H&P note should be written.
- If a patient does not require MICU admission, a consult note is written.
- Transfers from outside hospitals should be admitted under the accepting physician.
- If a patient is stable for transfer to the hospitalist service, the MAR needs to be contacted to determine the team/attending.
- The Fellow directly contacts accepting hospitalists.
- The ICU Resident signs out to the team resident.
- Transfer summaries should be written when there is more than 48 hours of ICU level care
- Death Note should be written in EPIC by pronouncing physician along with prompt EDRS completion
- The Fellow or Attending should be notified with changes in goals of care, new hemodynamic compromise, procedure complications, or death followed by a family update
- There should be timeouts before every procedure. The placement of CVCs should be confirmed via manometry or transducing before dilating, it is an institutional policy.
- Procedural consent is mandatory unless it is an emergency.
- All procedures require a note.
- MICU interdisciplinary conference is mandatory unless attending to patient care.

Night MICU Expectations:

- Confirm a Consult was placed in EPIC from the service asking for consultation
- Residents should present the consult to the fellow after completion (irrespective of the diagnosis)
- Any significant events such as: change in goals of care, hemodynamic compromise, procedure complication, or death should be notified to the fellow immediately with a family update
- Bounce backs apply at night as well
- MICU on call get the majority of admissions, however can give to the non-call team to make sure the difference in team size is not more than two patients
- Changes to ventilator should be notified to the Fellow and RT
- NEVER CHANGE THE VENTILATOR WITHOUT INFORMING THE RESPIRATORY THERAPIST AND ICU FELLOW!

Sepsis:

Key Terms:

- a. Systemic Inflammatory Response Syndrome (SIRS), need 2/4 positive
 - a. Leukocytosis (>12,000), BANDEMIA, Leukopenia or (<4,000)
 - b. Fever >100.4F OR Hypothermia < 96.8F
 - c. Tachypnea >20 breaths per minute
 - d. Tachycardia >90bpm
- b. Sepsis: SIRS + Suspected Infection
- c. Severe Sepsis: Sepsis + Evidence of Organ Dysfunction
- d. Septic Shock: Severe sepsis + hypotension DESPITE adequate resuscitation (20-30cc/kg, 2L of IVF over 30min) or Pressor requirement is needed

Sofa Criteria:

Table 1. Sequential [Sepsis-Related] Organ Failure Assessment Score^a

System	Score				
	0	1	2	3	4
Respiration					
PaO ₂ /FIO ₂ , mm Hg (kPa)	≥400 (53.3)	<400 (53.3)	<300 (40)	<200 (26.7) with respiratory support	<100 (13.3) with respiratory support
Coagulation					
Platelets, ×10 ³ /μL	≥150	<150	<100	<50	<20
Liver					
Bilirubin, mg/dL (μmol/L)	<1.2 (20)	1.2-1.9 (20-32)	2.0-5.9 (33-101)	6.0-11.9 (102-204)	>12.0 (204)
Cardiovascular					
MAP ≥70 mm Hg	MAP ≥70 mm Hg	MAP <70 mm Hg	Dopamine <5 or dobutamine (any dose) ^b	Dopamine 5.1-15 or epinephrine ≤0.1 or norepinephrine ≤0.1 ^b	Dopamine >15 or epinephrine >0.1 or norepinephrine >0.1 ^b
Central nervous system					
Glasgow Coma Scale score ^c	15	13-14	10-12	6-9	<6
Renal					
Creatinine, mg/dL (μmol/L)	<1.2 (110)	1.2-1.9 (110-170)	2.0-3.4 (171-299)	3.5-4.9 (300-440)	>5.0 (440)
Urine output, mL/d				<500	<200

Abbreviations: FIO₂, fraction of inspired oxygen; MAP, mean arterial pressure; PaO₂, partial pressure of oxygen.

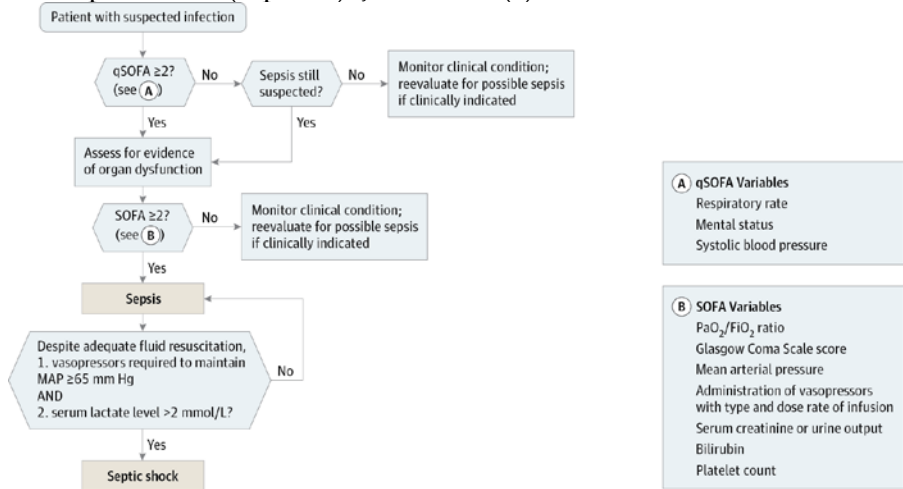
^a Adapted from Vincent et al.²⁷

^b Catecholamine doses are given as μg/kg/min for at least 1 hour.

^c Glasgow Coma Scale scores range from 3-15; higher score indicates better neurological function.

Reference: Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M., & Hotchkiss, R. S.

(2016). The third international consensus definitions for sepsis and septic shock (sepsis-3). *JAMA*, 315(8), 801-810.



Reference: Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M., ... & Hotchkiss, R. S. (2016). The third international consensus definitions for sepsis and septic shock (sepsis-3). *JAMA*, 315(8), 801-810.

Treatment:

- 1) Fluid resuscitation is essential!
 - a. Administer intravenous fluids aggressively. In general, give 30 mL/Kg of BW for fluid administration
 - b. Consider central line placement if needed for pressor support. Consider arterial line if significant hemodynamic instability.
 - c. Give 3 L of crystalloid fluids immediately
 - d. Will need on average 5L in the first six hours

-
- e. Crystalloids such as NS (\$2 per bag) are as effective as colloids (\$40 per bag) such as Albumin
- 2) Antibiotic administration early!
- a. Give appropriate broad-spectrum antibiotics early. Consider Vancomycin and Zosyn, if concern for ESBL can use Carbapenem such as Meropenem. Consider double pseudomonas coverage when mortality is over 25%. Mortality can be calculated with Apache II Score.
 - b. ICU Mortality increases by 7% per hour of no antibiotics in hypotensive patients. Culture before antibiotic administration with blood, sputum, and urine cultures. In particular situations consider meninges and bone as sources of infection.
 - c. Lactic Acid is recommended, the rate of decrease with treatment is a better predictor than the absolute value.
- 3) Vasopressors
- a. Start Pressors early if after adequate fluid resuscitation. MAP remains <65 mmHg. Pressors can be started and continued peripherally until patient is stabilized. There is NO policy against starting pressors peripherally.
 - b. Start with norepinephrine first. Consider adding vasopressin next. Agents that can be used as third pressors: epinephrine, dobutamine, phenylephrine. Dopamine increases the rates of arrhythmias and should be used judiciously.

Vasopressors: Used for Shock when MAP < 65

Causes of Shock:

- 1) Septic Shock
- 2) Cardiogenic Shock
- 3) Neurogenic Shock
- 4) Anaphylactic Shock

Goal Mean Arterial Pressure is generally > 65 mm Hg. However this goal can vary in the setting of neurological injury such as stroke or intracranial hemorrhage. There is sufficient evidence that Norepinephrine should be the first vasopressor used in all situations even if used peripherally. If blood pressure does not increase appropriately with norepinephrine, either vasopressin or epinephrine can be next. Dopamine has shown an increase in mortality and arrhythmias, and should be used cautiously. Phenylephrine is most commonly used for neurosurgical or spinal injury. In severe Congestive Heart Failure exacerbations ionotropic agents such as Dobutamine and Milrinone can be used, however due to their Beta-2 receptor stimulation, hypotension can worsen and concomitant use of norepinephrine may be needed. Below are the specific receptors that these agents work on.

Vasopressor	Alpha 1	Beta 1	Beta 2
Norepinephrine	+++	+	—

Vasopressin	_____	_____	___
Epinephrine	+++	+++	+++
Phenylephrine	+++	_____	___
Dopamine	++ (High Dose)	+++	+++
Dobutamine	_____	++	+
Milrinone	_____	_____	___

Vasopressin works on V2 receptors stimulating the RAAS system, which increases blood volume, cardiac output, and arterial pressure. Milrinone is a phosphodiesterase-3 inhibitor and should be used with caution in patients with renal dysfunction.

Suggested order for Vasopressor Support for Septic Shock

- 1) Norepinephrine
- 2) Vasopressin
- 3) Epinephrine
- 4) Phenylephrine
- 5) Dopamine (If there is bradycardia, keep in mind Dopamine can increase mortality)

* Vasopressin and or Epinephrine can be interchanged at 2/3

Reference: Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M. & Hotchkiss, R. S.

(2016). The third international consensus definitions for sepsis and septic shock (sepsis-3). *JAMA*, 315(8), 801-810.

Vitamin C, Steroids, and Thiamine

The early use of IV Vitamin C, Hydrocortisone, and Thiamine has been shown to decrease mortality in septic shock, along with preventing organ dysfunction.

However these findings are recent and more data needs to be collected to validate these claims.

Refernce: Marik, P. E., Khangoora, V., Rivera, R., Hooper, M. H., & Catravas, J. (2017). Hydrocortisone, vitamin C, and thiamine for the treatment of severe sepsis and septic shock: a retrospective before-after study. *Chest*, 151(6), 1229-1238.

Steroids in Septic Shock:

There is a thought that it is actually the steroids that result in the mortality benefit. Annane et al which is a 1241 person study showed that 50 mg of IV Hydrocortisone q6h and Fludrocortisone 50 ug daily via an NG tube reduced 90 day mortality in septic shock patients compared to a placebo group, along with vasopressor free days and organ failure free days.

However once again there is more data that needs to be collected on these new intervention for sepsis.

Reference:

Annane, D., Renault, A., Brun-Buisson, C., Megarbane, B., Quenot, J. P., Siami, S., & Timsit, J. F. (2018). Hydrocortisone plus fludrocortisone for adults with septic shock. *New England Journal of Medicine*, 378(9), 809-818.

Respiratory Failure:

Hypoxemia - $\text{PaO}_2 < 60 \text{ mmHg}$

O₂ controlled with PEEP and FiO₂

Hypercapnia - $\text{PaCO}_2 > 45 \text{ mmHg}$ (however in COPD baseline PaCO_2 is often higher)

CO₂ controlled with Respiratory Rate and Tidal Volume

Diagnostic Tests to order in Acute Respiratory Failure: CXR and ABG STAT

Therapies to Consider: Lasix if hypervolemic, Chest Physiotherapy and suctioning if excessive secretions present

Acute Respiratory Distress Syndrome (ARDS)

Berlin Criteria:

- 1) $\text{PaO}_2/\text{FiO}_2 < 300$ -200 (mild), <200 -100 (moderate), <100 (severe)
- 2) Respiratory insult within seven days
- 3) Bilateral infiltrates on chest xray
- 4) Cardiogenic cause ruled out (echocardiogram appropriate)

5) A minimum PEEP of 5 cm H₂O being used

Mainstay treatment is low tidal volume ventilation (4-6 mL/kg of IBW) to target a plateau pressure <30 cm H₂O

The goal of therapy is not to normalize pH or PaCO₂.
Permissive respiratory acidosis (hypercapnia) improves outcomes.

PaO₂ of ≥ 55 mmHg is appropriate

Consider:

- 1) Paralytic therapy if PaO₂/FiO₂ <150
- 2) Prone positioning if PaO₂/FiO₂ < 150 and FiO₂ $\geq 60\%$

If the patient not responding to conventional therapy consider ECMO

Reference: Kallet, R. H., Jasmer, R. M., Pittet, J. F., Tang, J. F., Campbell, A. R., Dicker, R., ... & Luce, J. M. (2005). Clinical implementation of the ARDS network protocol is associated with reduced hospital mortality compared with historical controls. *Critical care medicine*, 33(5), 925-929.

Mechanical Ventilation:

Mechanical Ventilation is one of the more complex entities in the Intensive Care Unit, this guide provides a brief overview

Oxygenation is controlled by PEEP and FiO₂

CO₂ is controlled by RR and TV

Volume Assist-Control:

Requires the rate and tidal volume to be set. If the patient wants to breathe more than the set rate they can by triggering the vent which will then deliver the volume. The plateau pressure is the distending pressure of the alveoli. A safe plateau pressure is less than 30 cm H₂O.

Pressure Assist-Control:

Requires the rate and control pressure to be set. All of the modern vents have a combined assist and control mode. Inspiratory time is the time it takes the ventilator to deliver one breath (expiratory time being the opposite) The ventilator goes up to a set pressure and continues at this pressure until it turns off (known as I-time). In spontaneous breathing the ratio of I-time and E-time is (I:E ratio) 1:2 -1:4, and this should be maintained in ventilated patients. In order to set the I:E ratio consider the rate of breaths per minute (for instance 20 BPM, 60

sec per min then 3 seconds per breath, if the I-time is 1 second then the expiratory time is 2, meaning 1:2 ratio).

Pressure Support Ventilation:

Requires pressure support and PEEP to be set.

This allows a patient to breath spontaneously, therefore its imperative that a patient has a competent drive to breath.

When the patient triggers the ventilator, the machine will deliver a breath by increasing the pressure in the circuit. The amount delivered depends on the compliance of the lungs.

When a patient triggers the vent, the pressure increases from the PEEP to the PEEP + Pressure support. Because of the varying compliance in the lungs, the patient will have variable tidal volumes.

Volume Support Ventilation:

Requires tidal volume and PEEP to be set.

The ventilator will automatically adjust the pressure support to get the desired volume. The mode also allows the patient to spontaneously breath.

Airway Pressure Release Ventilation (APRV):

Inversed ratio high pressure control mode of mechanical ventilation. It allows for spontaneous breathing at high lung volumes. Often used as a “rescue” mode if the previous modes on mechanical ventilation failed. Consider should be adequately sedated or else will fight the vent.

Common Vent Setting for the various modes:

Volume 6-10 mL/kg IBW (non-ARDS)

PEEP 5-20

Rate 10-25

Pressure control: 5-25

Phigh 20-30, small changes will have big effects

Flow always is ZERO, don't change it
Thigh 3-6 s, change in increments of 0.5s and get ABG
Tlow 0.4-0.8 s, change in increments of 0.1s and get ABG

Liberation from Mechanical Ventilation:

Rapid shallow breathing index= Respiratory Rate/Tidal Volume

Where RSBI < 105 Successful Weaning Predicted
Where RSBI > 105 Failure predicted

Weaning from the vent or extubation should be considered when the patient is requiring minimal support from the vent, i.e., they are drawing adequate tidal volumes, FIO₂ is minimal (< 50%) and respiratory rate is < 35

In order to determine if patient is ready to be weaned from the vent there are four questions that need to be asked:

- Is the case of respiratory failure reversed?
- Is there a strong cough?
- How is the patient mentating?
- Are there are lot of secretions?

Consider doing a spontaneous breathing trial if the answer is yes to all of the above. Patient should be off sedation completely, put on pressure support for approximately 30-120 min. If they are pulling good tidal volumes, extubation should be attempted.

Other considerations are: Being off sedation, no vasopressor support, ability to protect airway, secretion burden not excessive, RSBI < 105.

Perform daily withholding of sedation and once daily spontaneous breathing trials if the patient is ready.

SBT should be performed with pressure support of 5-8 cmH₂O (preferred) or CPAP of 5 cmH₂O.

Reference: The ARDS Network Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome *N Engl J Med.* 2000; 324: 1301-1308

COPD:

Outpatient COPD management:

# of exacerbations	CAT < 10	CAT > 10
FEWER < 2 outpatient	GROUP A	GROUP B
	SABA	LABA OR LAMA
MORE > 2 outpatient or 1 inpatient	GROUP C	GROUP D
	LABA+LAMA	LABA+LAMA+ICS

Consider Pulmonary Rehabilitation starting at Group B

Abbreviations: SABA – Short acting beta agonist, LABA – Long acting beta agonist, LAMA – Long acting muscarinic antagonist, Inhaled corticosteroids, CAT – COPD Assessment Score

Clinical Features of exacerbation: Increased sputum production, shortness of breath, wheezing, increased work of breathing, tachypnea, tachycardia, smoking for over 20 years.

Labs to order: CBC, CMP, CXR, ABG, and Respiratory Panel
Monitor: Continuous monitoring of Oxygen, RR, HR, Cardiac Monitoring, and Glucose

COPD Exacerbation Treatment:

- **Aggressive bronchodilator therapy** (Albuterol 2.5 mg diluted to 3 mL via nebulizer every 2 hours, Ipratropium 500 micrograms via nebulizer or 4 to 8 inhalations from MDI every four hours)
- **Glucocorticoids** (eg, methylprednisolone 40 BID or Prednisone 40 mg for five days),
- **Antibiotics** (Low Pseudomonas risk – IV Ceftriaxone 1 g daily and Azithromycin 250 mg daily for five days) (Pseudomonas Risk – IV/PO Levofloxacin 750 mg daily, Piperacillin-Tazobactam 3.375 g q8h IV, OR Cefepime 1 to 2 grams q8h IV, OR Ceftazidime 1 to 2 grams q8h IV). For Influenza Positive patients use. Antiviral therapy (influenza suspected): Oseltamivir 75 mg orally every 12 hours.
- Assess respiratory status, if Hypercapnic and acidemic (7.20-7.35) consider **Non-Invasive Ventilation** such as BiPap, however if ABG not improving, clinical status worsening, and pH < 7.2 consider mechanical ventilation.

Provide Oxygen to keep saturations over 80%

References:

-
1. Dodd JW, Hogg L, Nolan J, et al. The COPD assessment test (CAT): response to pulmonary rehabilitation. A multicentre, prospective study. *Thorax* 2011; 66:425.
 2. Dodd JW, Marns PL, Clark AL, Ingram KA, Fowler RP, Canavan JL, et al. The COPD Assessment Test (CAT): short- and medium-term response to pulmonary rehabilitation. *COPD* 2012; 9:390.

Asthma Outpatient Management:

Step 1	Step 2	Step 3	Step 4	Step 5
SABA	Low Dose ICS	Medium ICS + LABA	High Dose ICS + LABA	High Dose ICS + LABA + Omalizumab

NEVER GIVE LABAs alone in asthma, it increases mortality!

The mainstay treatment of chronic asthma is ICS.

Labs to order in an exacerbation: CBC, CMP, CXR, ABG, and Respiratory Panel

Monitor: Continuous monitoring of Oxygen, RR, HR, Cardiac Monitoring, and Glucose

Asthma Exacerbation Treatment:

- **Aggressive bronchodilator therapy** (Albuterol 2.5 mg diluted to 3 mL via nebulizer every 2 hours, Ipratropium 500 micrograms via nebulizer or 4 to 8 inhalations from MDI every four hours),
- **Glucocorticoids** (eg, methylprednisolone 40 BID or Prednisone 40 mg for five days).
- **Non Invasive Ventilation** (for Respiratory Acidosis with pH > 7.20). **Intubation** if severe acidosis (pH < 7.20 or failure of NIV).
- Normalization of ABG can suggest severe exacerbation, pay close attention to the clinical status

GI Bleeding in the ICU

Any GI bleed with hemodynamic compromise warrants ICU admission, however it can be warranted by excessive blood loss alone.

Differentials of Upper GI Bleed:

- Gastric/Duodenal Ulcers
- Esophageal Varices
- Mallory Weiss Tears
- Malignancy: Esophageal, Gastric, Duodenal
- Gastritis
- Dieulafoy's Lesion
- GAVE
- Hematobilia

Differentials of Lower GI Bleed:

- Diverticulosis

-
- Ischemic/Infectious/Radiation Colitis
 - AV Malformation
 - Hemorrhoids
 - Malignancy: Colon and Rectal
 - Mesenteric Ischemia
 - Post Polypectomy

Initial Assessment

- a. Check for orthostasis, which suggests significant blood loss
- b. Hemoglobin will take hours to reflect acute blood loss, do not follow Hemoglobin in hypovolemic shock, follow vital signs and nursing report of blood loss amount
- c. Assess what anticoagulation medications the patient is on and if there is reversal agent available
- d. Lavage with NG tube to determine if it is an upper or lower GI source

Management

- a. Establish IV access with 2 large bore peripheral lines (size 18 or bigger), give fluids through large bore IVs as fluids will be administered faster, peripheral catheters are shorter and larger diameter compared to CVC.
- b. Consults to GI, Interventional Radiology, and General Surgery as warranted depending on the clinical situation. If hemodynamically unstable arrange an Angiogram with IR STAT, have Surgery on stand by in case intervention fails
- c. Resuscitate intravascular volume with IVF and RBCs
- d. PRBCs transfusion is preferred until hemodynamic stability is achieved and blood loss subsides. If the

bleeding is without shock and mild, hemoglobin of ≥ 7 is the target.

- e. Normal Saline is preferred.
- f. LR can bind with citrate from PRBCs and form clots
- g. Massive Transfusion Protocol can be used if bleeding is severe, this protocol has to be approved by the MICU or Trauma Attending.
- h. Correct bleeding diatheses, patient is losing whole blood not just PRBC. Rule of thumb is 3:1:1 of PRBC: FFP: Platelets
- i. INR to less than 1.5 with K-Centra (reverses within one hour) or Vitamin K (reverses within 24-48 hours). Any life threatening bleed should be reversed with K-Centra, this includes intracranial hemorrhage or GI bleeds.
- j. If hemodynamically unstable suspected UGIB, bolus 80 mg of IV Pantoprazole and start a drip at 8 mg/hr. Octreotide is reserved for esophageal varices, 40 mg bolus with drip at 4 mg/hr.
- k. EGD/Colonoscopy with intervention 24 hours

References:

Feinman, M., & Haut, E. R. (2014). Upper gastrointestinal bleeding. *Surg Clin North Am*, 94(1), 43-53.

Ghassemi, K. A., & Jensen, D. M. (2013). Lower GI bleeding: epidemiology and management. *Current Gastroenterology Reports*, 15(7), 333.

Diabetic Ketoacidosis (DKA)/ Hyperosmolar Hyperglycemic State (HHS)

Diagnostic criteria of DKA:

- Blood sugar > 250 mg/dl (Euglycemic DKA has been reported)
- pH < 7.3
Elevated anion gap not explained by other condition
- Serum bicarbonate < 20 mEq/L
- Urine Ketones, Acetone, and BHB > 2

Diagnostic criteria of HHS:

- Blood sugar > 600 mg/dl and osmolality > 320 mOsm/L
- pH > 7.3
- Serum bicarbonate > 20 mEq/L

Management of DKA and HHS:

1. Aggressive fluids resuscitation is the very first thing that should be done. Replace fluid losses over 24hrs, IVF to expand extracellular fluid volume without abrupt fall in plasma osmolality, then switch to 1/2 NS once volume repleted. May have to add KCl to fluids if K is 3.3-5.0, as Insulin will drive K into cell. K < 3.3 and Insulin Drip should be stopped
2. Insulin Drip should be started as soon as possible. It stops lipolysis and the hepatic production of ketoacids. Loading dose 0.1-0.15 units/kg IV then continuous infusion that is appropriately titrated. Target the blood glucose level to decline by 70-100 mg/dl per hour.
3. Give glucose (IV D5 1/2NS) when the serum glucose level falls below 200
4. Replace electrolytes aggressively, pay close attention to Potassium, and Phosphorous BMP q4h. Aiming for 2 anion gaps to close and then can give SQ Lantus with overlap with Insulin Drip for two hours

Reference: Gosmanov, A. R., Gosmanova, E. O., & Dillard-Cannon, E. (2014). Management of adult diabetic ketoacidosis. *Diabetes, metabolic syndrome and obesity: targets and therapy*, 7, 255.

Stepwise Approach to Acid/Base Disorders

- #1 Step 1: Evaluate internal consistency of the ABG, pH, PaCO₂, HCO₃⁻. Disorders in the same direction as the blood pH are primary disorders
- #2 ALWAYS calculate the Anion Gap.
Na - (Cl+HCO₃⁻). Normal is 12
Anion Gap >12 is primary AG metabolic acidosis
AG<12, HCO₃⁻<24 is non AG metabolic acidosis
- #3 Is Anion Gap appropriate for the HCO₃⁻?
>30 is Primary Metabolic alkalosis

24-30 is no additional disturbances

<24 Primary non anion gap metabolic acidosis

4 Is the PaCO₂ appropriate for the HCO₃

PaCO₂ (expected)= 1.5(HCO₃)+8

Expected>Observed is concomitant RAI

Expected=Observed is Resp Compensation

Expected <Observed is concomitant resp acidosis

Tip: To estimate expected PaCO₂, the last 2 digits of pH equal the expected pCO₂.

Other Compensatory Equations:

Met Alkalosis: PaCO₂ increases by 0.7 for each 1 increase of HCO₃

Resp Acidosis (acute): HCO₃ increases by 1 for each 10 increase of CO₂

Resp Acidosis (chronic): HCO₃ increases by 3.5 for each 10 increase of CO₂

Resp Alkalosis (acute): HCO₃ decreases by 2 for each 10 decrease of CO₂

Resp Alkalosis (chronic): HCO₃ decreases by 5meq for each 10 decrease of CO₂

Sedation:

The goals of sedation in the ICU are to decrease anxiety and agitation, provide amnesia, reduce patient-ventilator dyssynchrony, decrease respiratory muscle oxygen consumption, to some extent relieve pain, and facilitate nursing care. Excessive sedation leads to higher length of ICU stay, prolonged days on mechanical ventilation and higher delirium rates. The ideal level of sedation is one that achieves a calmed patient, able to follow commands and participate in physical therapy. Not all patients may reach the latter.

Pharmacotherapy:

1. Benzodiazepines: bind to GABA receptors, acting as an inhibitory neurotransmitter. They are sedative, hypnotic, amnestic, anticonvulsant, anxiolytic and to some extent muscle relaxant but generally provide no analgesia and patients can develop tolerance. They provide synergistic effect with opiates. They are in general lipid soluble, with good oral bioavailability, metabolized in the liver (except lorazepam, oxazepam and temazepam), and are excreted in the urine. The lipid solubility determines the onset and duration of action.
 - a. Diazepam (Valium): Potent tranquilizer, muscle relaxant and anticonvulsant with rapid onset but long half life. Difficult to use in continuous infusion because of the large volume of distribution and the accumulation of active metabolites. Also propylene glycol solvent accumulation limits infusions. It is hence used for short courses in intermittent dosing, mostly in alcohol withdrawal or seizures due to drug overdose or poisoning. Go-to dosing 0.03 to 0.1 mg/kg q0.5-6H
 - b. Lorazepam (Ativan): Slow onset, moderate duration of action when administered short term by intermittent infusions. Risk of over-sedation when titrating due to delayed response and accumulation in peripheral tissues. Metabolism not affected by liver disease. It is a good choice for longer term sedation because it does not form active metabolites and has low propensity for interactions. Propylene glycol solvent may accumulate with prolonged use or high dosing causing metabolic acidosis and end-organ dysfunction. Go-to dosing: 0.02 to 0.06 mg/kg q2-6H.

-
- c. Midazolam (Versed): Fast onset, short duration when hepatic function is intact. Accumulates when given in infusion >48 hours because of redistribution and formation of active metabolite. Usually the most commonly used benzodiazepine in the ICU, mainly for drips. It is a good choice for short-term anxiolysis and treatment of acute agitation. Go-to dosing 0.02 to 0.1 mg/kg/hour infusion.
 2. Propofol: Activates central GABA and also modulates hypothalamic sleep pathways. It is hence a sedative, anesthetic, amnestic, anticonvulsant which can cause respiratory and cardiovascular depression. It is highly lipid soluble, has immediate onset and rapid awakening upon discontinuation when administered for short-term use. Its clearance is not changed in liver or kidney disease and dosing is easily titratable to depth of sedation required. There is unpredictable respiratory depression and hence used is mostly limited to mechanically ventilated patients and is a good choice in conjunction with appropriate analgesia for short-term sedation of patients in whom rapid awakening is advantageous. Some of the side effects are hypotension, bradycardia, respiratory depression, decreased myocardial contractility, elevated triglycerides, peripheral injection site pain, and rarely propofol infusion syndrome. Go-to dosing: 5 to 50 mcg/kg/minute with titration thereafter.
 3. Antipsychotics:
 - a. Haloperidol: Butyrophenone anti-psychotic tranquilizer with slow onset. It is a moderately sedating cortical dopamine-2 antagonist for control of positive symptoms of delirium and ICU psychoses. Minimal cardiorespiratory effects in euvolemic, hemodynamically stable patients. There is no

respiratory depression or hypotension seen and is useful in agitated, delirious, and psychotic patients. Some of the side effects include QT prolongation, Neuroleptic malignant syndrome. Go-to dosing: 0.03 to 0.15 mg/kg every 30 minutes to six hours.

- b. Atypical Antipsychotics such as Quetiapine, and Ziprasidone. These have less EPS effects, be cognizant of QT prolonging. Seroquel is primarily used at a dose of 50-100 mg. Ziprasidone 80 mg can be used, minimal side effects compared to the other antipsychotics.
4. Precedex (dexmedetomidine): Commonly used agent in the ICU. It is a central sympatholytic acting on alpha-2 receptors. Causes moderate anxiolysis and analgesia, but has no clinically significant effect on respiratory drive. Character and depth of sedation may permit critically ill and mechanically ventilated patients to be interactive or easily awakened, yet comfortable. Can be used in non-mechanically ventilated ICU patients and continued as needed following extubation. It is also less likely to cause delirium than other sedatives. It is a good choice for short- and long-term sedation in critically ill patients without relevant cardiac conditions. Disadvantages include potentially significant hypotension and bradycardia or hypertension that do not resolve quickly upon abrupt discontinuation. Go-to dose: Initiate at 0.2 mcg/kg/hour and titrate every 30 minutes.
5. Ketamine: A potent dissociative sedative-anesthetic with marked analgesia that maintains cardiac output and mean arterial pressure without inhibition of respiratory drive. It is used as an alternate choice for postsurgical pain management, severe agitation, or as an adjunctive analgesic in patients with severe

refractory pain. Adverse effects may include hallucinations, delirium upon withdrawal, dissociative experiences, and accumulation of active metabolites in renal and hepatic impairments. Go-to dosing: 0.05 to 0.4 mg/kg/hour after initial loading of 0.1 to 0.5 mg/kg

6. Opiates are commonly used analgesics which also contribute to sedation. Their use is described under the topic analgesics.
7. Adjuncts: Tylenol, NSAIDs, anti epileptics

Delirium:

- a. Disturbance in attention (ie, reduced ability to direct, focus, sustain, and shift attention) and awareness.
- b. Change in cognition (eg, memory deficit, disorientation, language disturbance, perceptual disturbance) that is not better accounted for by a preexisting, established, or evolving dementia.
- c. The disturbance develops over a short period (usually hours to days) and tends to fluctuate during the course of the day.

-
- d. There is evidence from the history, physical examination, or laboratory findings that the disturbance is caused by a direct physiologic consequence of a general medical condition, an intoxicating substance, medication use, or more than one cause.
 - e. It is characterized by impaired cognition with nonspecific manifestations. In critically ill patients, it may develop secondary to multiple precipitating or predisposing causes. Although it can be a transient and reversible syndrome, its occurrence in Intensive Care Unit (ICU) patients may be associated with long-term cognitive dysfunction.

Delirium in ICU patients is associated with increased duration of mechanical ventilation, prolonged hospitalization, increased rates of self-extubation, and increased risk of mortality. It may also contribute to long-term cognitive dysfunction.

Risk factors: Infection, Withdrawal (Etoh, Sedatives), Acute Metabolic (renal/liver failure, electrolytes, etc), Trauma, CNS Pathology, Hypoxia, Deficiencies (B12, thiamine, folate, niacin), Endocrine (hyper/hypo), Acute vascular, Toxins, Heavy metals

Monitoring: RASS= Richmond Agitation Sedation Scale, as described in sedation. CAM-ICU = Confusion Assessment Method: This takes only minutes and has high sensitivity and specificity. This instrument has been developed and validated for identification of delirium in the intensive care unit

Management:

- f. Non pharmacological
 1. Orientation and reorientation
 2. Early mobility
 3. Promote effective sleep/wake cycles

-
4. Environmental control including lighting, temperature, noise, humidity
 5. Management of hunger, thirst, bowel, bladder along with provision of eyeglasses, hearing aids, and timely removal of catheterization and restraints
 6. Appropriate explanation prior to and prophylactic pain management during procedures
 7. Source of entertainment and distraction including regular family visits, TV, radio, spiritual care to the patient.
 8. Cognitive behavioral therapy and relaxation techniques.
 - 9.
- g. Pharmacological:
1. Pain relief
 2. Correcting underlying cause with infection control with antibiotics, correction of metabolic derangements, replacement of micronutrient deficiencies
3. Sedation with:
- 1) Dexmedetomidine
 - 2) Propofol
 - 3) Avoid benzodiazepines except in ETOH withdrawal
 - 4) Antipsychotics
- a. Haloperidol: Butyrophenone antipsychotic which is considered a cortical dopamine (D2) receptor antagonist. The effective dose for ICU delirium depends on the severity of the delirium. Go-to dose: 2-10 mg IV Q6H. Adverse side effects of this medication are extrapyramidal symptoms such as acute dystonic reactions, subacute Parkinsonism, akathisia, dose-dependent QTc prolongation, and neuroleptic malignant syndrome.
- b. Atypical antipsychotics: An alternative approach to haloperidol involves the use of olanzapine, risperidone, quetiapine, or ziprasidone, which are the second-generation atypical

antipsychotics. These atypical antipsychotics are associated with less extrapyramidal symptoms when compared with haloperidol.

- c. Olanzapine: Potential alternative or add-on to as-needed IV haloperidol for treatment of acute agitation and/or delirium in the ICU. Adverse effects include orthostatic hypotension, hyperglycemia, somnolence, QT interval prolongation, aplastic anemia and anticholinergic effects. Go-to dosing: Initially 5 to 10 mg once daily; increase every 24 hours as needed by 5-mg increments up to 20 mg/day
- d. Quetiapine: Similar potential alternative to haloperidol, dose reduction needed in hepatic insufficiency. Go-to dosing: Initially 50 mg every 12 hours; increase every 24 hours as needed up to 400 mg/day

References: Zalieckas, J., & Weldon, C. (2015, February). Sedation and analgesia in the ICU. In *Seminars in pediatric surgery* (Vol. 24, No. 1, pp. 37-46). Elsevier.

Common ICU Drips

Name	Std. conc	Start rate	Max rate	Comments
Sedatives, analgesics and paralytics				

Propofol	1000mg/100mL	10 mcg/kg/min	60 mcg/kg/min	Infusion syndrome may occur within 4 days and has high mortality (33%). Rapid onset, quick recovery but may accumulate with prolonged use and last longer.
Fentanyl	50 mcg/mL	25 mcg/hr	300 mcg/hr	No dose adjustment required in renal or hepatic disease. Go to analgesic in ICU
Dexmedetomidine	4 mcg/mL	0.2 mcg/kg/hr	1.5 mcg/kg/hr	Presynaptic alpha-2 agonist which is a favored sedative in the ICU, low side effect profile and ease of use in non-mechanically ventilated patients
Midazolam	1 mg/mL	1 mg/hr	20 mg/hr	No specific dose adjustment required in renal or hepatic disease but use with caution. Commonly used in ICU sedation and procedural sedation
Cisatracurium	1 mg/mL	0.5 mcg/kg/min	10 mcg/kg/min	Paralytic of choice in renal or hepatic insufficiency. Minimal and transient side effects
Ketamine	5 mg/mL			Different doses for induction, maintenance of anesthesia and for analgesia. Useful in status asthmaticus and refractory pain
Morphine	1 mg/mL	0.2 mg/hr	30 mg/hr	Only for severe pain where other analgesics are inadequate. Try to avoid in renal dysfunction in favor of other analgesics. Boxed warning regarding life threatening respiratory depression
Hydromorphone	1 mg/mL	0.5 mg/hr	3 mg/hr	Parenteral formulation up to 5 times more potent, dose reduction required for both renal and hepatic dysfunction. Boxed warning regarding life threatening respiratory depression.
Cardiovascular agents				
Norepinephrine	32 mcg/mL	2 mcg/min	40mcg/min	Vasopressor of choice in most conditions to start off with. Central line. Phentolamine the antidote for extravasation ischemia. No dose adjustment required in renal or hepatic disease.
Vasopressin	0.2	2.4 units/hr	2.4 units/hr	Generally not titrated in our ICU.

	units/mL			Most attendings prefer this to be added on as the second pressor as soon as levophed requirement goes higher than double digits. No dose adjustment required in renal or hepatic disease.
Phenylephrine	400 mcg/mL	10 mcg/min	400 mcg/min	Pure alpha agonist. Central line preferred. Not recommended for routine use in septic shock.
Epinephrine	32 mcg/mL	1 mcg/min	10 mcg/min	Much more used in ACLS, anaphylaxis (IM is preferred). Central line if infusion. No dose adjustment required in renal or hepatic disease. Phentolamine the antidote for extravasation ischemia.
Dobutamine	1000 mcg/mL	2.5 mcg/kg/min	20 mcg/kg/min	Does not specifically raise blood pressure but used for inotropic effects. Levophed still preferred as first line in cardiogenic shock. No dose adjustment required in renal or hepatic disease.
Dopamine	1600 mcg/mL	5 mcg/kg/min	20 mcg/kg/min	Increases rate of arrhythmias in the ICU
Amiodarone	1.8 mg/mL	1 mg/min * 6 hrs followed by 0.5 mg/min for 18 hours f/b oral maintenance for stable VT and A fib		Class III antiarrhythmic. Pulmonary and hepatic toxicities problematic, arrhythmogenic. Consider dose adjustment in hepatic dysfunction. Difficult pharmacokinetics to predict.
Diltiazem	1 mg/mL	2.5 mg/hr	20 mg/hr	May bolus initially for rapid rate control. No dose adjustment required in renal or hepatic disease.
Esmolol	20 mg/mL	50 mcg/kg/m	300 mcg/kg/m	May bolus initially for rapid rate control. No dose adjustment required in renal or hepatic disease.
Furosemide	1 mg/mL	2.5 mg/hr	160 mg/hr, upto 240 mg/hr, with high rates having risk of ototoxicity	Higher doses required in renal dysfunction for desired response but avoid in oliguric/anuric states. Important to closely follow the electrolytes and replace accordingly
Bumetenide(Bumex)	0.25 mg/mL	0.5 mg/hr	2 mg/hr	Contraindicated in anuria, use with caution in oliguria. More

				potent than Lasix, important to closely follow the electrolytes and replace accordingly
Nitroprusside	400 mcg/mL	0.1 mcg/kg/min	8 mcg/kg/min	Cyanide toxicity risk in renal insufficiency and prolonged admin. Can cause precipitous hypotension. Limit rate in renal dysfunction. Can also cause methemoglobinemia in select patients. Use may elevate ICP
Nitroglycerine	400 mcg/mL	10 mcg/min	200 mcg/min	Increases ICP, caution in TBI. Hemodynamic and antianginal tolerance develops in 24-48 hrs. nitrate free interval required. No dose adjustment required in renal or hepatic disease.
Nicardipine	50 mg/250 mL	5 mg/hr	15 mg/hr	Used mostly in hypertensive emergency, especially when BP is the only contraindication for reperfusion therapy with tPA in acute ischemic stroke
Labetalol	1.2 mg/mL	0.5 mg/min	2 mg/min	Good agent to start off with in hypertensive emergency, especially in pregnancy. Safe in pregnancy. No dose adjustment required in renal or hepatic disease. Can administer a bolus for quicker control if required
Sodium Bicarbonate	25 mEq	NS with 8.4%, 25 meQ	150 meQ	Used for severer refractory acidosis in selected clinical situations. May worsen outcomes.
Milrinone	200 mcg/mL	0.25 mcg/kg/min	1 mcg/kg/min	Accumulates in renal failure, dose adjustment recommended. Short term iv therapy of acute decompensated heart failure.
Miscellaneous				
Insulin	1 unit/mL	0.1 unit/kg/hr	0.15 unit/kg/hr	Follow DKA protocol in DKA and hyperglycemia protocol in non DKA hyperglycemia as iv insulin is the best control for a critical setting. Also used for hypertriglyceridemia. Close monitoring of glucose and potassium paramount
Heparin	50 Units/mL			Low dose protocol for ACS/Stroke given the arterial and low clot burden. High dose protocol for VTE, Afib and PE given venous and/or high clot burden. Monitor with aPTT or anti Xa

Naloxone	0.04 mg/mL	0.25 mg/hr	10 mg/hr	For use with exposures to long-acting opioids (eg, methadone), sustained release product, and symptomatic body packers after initial naloxone response. The goal is to titrate for a respiratory rate of 10-12 BPM and not for a specific mental status.
Argatroban	1000 mcg/mL	0.5 mcg/kg/min	10 mcg/kg/min	Anticoagulant of choice in HIT. Monitored with aPTT