The University of Michigan
CICU Handbook

MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

Acknowledgements

Ahmad A. Abdul-Aziz, MD

Ran Lee, MD

Sarah Adie, PharmD

Michael P. Thomas, MD

Table of Contents

CICU Rounding Guide for the House Officer 5

CICU Rounding Document 7

Hemodynamics 8

- Normal Hemodynamics 8
- Hemodynamic Profile of Shock States 8

Critical Care Equations 8

Mechanical Ventilation in the CICU 9

- Traditional Nasal Cannula 9
- High Flow Nasal Cannula 9
- Non-Invasive Positive Pressure Ventilation 9
- Invasive Mechanical Ventilation 9
- Respiratory Support in Pulmonary Edema 10
- Respiratory Support in Cardiogenic Shock 11

Common CICU Medications 12

- Vasopressor, Inotrope, and Vasodilator Properties 12
- Vasopressors 12
- Inotropes 13
- Vasodilators 13
- Diuretics 14
- IV Antihypertensives 14
- Rate Control 15
- Antiarrhythmics 15
- $P2Y_{12}$ Antagonists 16

Sedation 16

- Hemodynamic and Cardiac Effects of Antipsychotic and Sedative Agents 16
- Proposed Sedation Algorithm in the Critically Ill Cardiovascular Patient 17

Pulmonary Artery (“Swan-Ganz”) Catheterization 18

- Indications 18
- Absolute and Relative Contraindications 18
- Complications 18
- Monitoring 18
- Waveforms 19

Intra-Aortic Balloon Pump 19
Indications 19
Contraindications 19
Complications 20
Mechanism 20
Monitoring 20
Timing 20
Impella 22
Indications 22
Contraindications 22
Mechanism 22
Complications 22
Monitoring 22
Targeted Temperature Management and Induced Hypothermia 23
Indications and temperature goals 23
Goal: sustain cooling for at least 24 hours 24
Phase I: Cooling 24
Phase II: Maintenance 25
Phase III: Transition to Rewarming and Controlled Rewarming 25
Algorithm 1: Overcoming Shivering During Induced Hypothermia 27

CICU Rounding Guide for the House Officer

General principles

-Clear, concise, and regimented rounding with topics in the same expected order, every time
-Non-rounding resident or intern has interval EKGs, CXRs, or other scans pulled up for efficiency, can also help with orders
-Go out on a limb with assessments and plans, if you aren't sure, pick what seems most reasonable. There is no punishment for being "wrong" and often there is no right or wrong answer.
-ICU plans should always be measurable and discrete ("We will diurese 2L today as our goal" not just "I'd like to get fluid off")
-Total goal is 5-10 minutes per patient without interruptions, which is achievable with time/practice

Brief one-liner

-Patient's name, age, 5-10 second story of why here (don't need to do this if we all know the patient from before)

Nursing update

-Nurse will say his or her update in ABCDEF format

Major interval events

-Keep this to a minimum; many things happen in the ICU (consultant visits, scans, lab results not necessary unless earth-shattering)
-Can include major changes in condition (e.g. patient who was doing well has sudden become hypotensive requiring inotropes, patient coded overnight, patient went into a-fib with RVR, etc.)

Current medications

List vasoactive drips and doses first, followed by other cardiac medications, antibiotics next (with day number and proposed end date), then everything else. Please list all medication orders. Irrelevant or outdated medications should be discontinued by another resident or intern at this time.

Vitals Review

-For BP, please focus on MAPs and their trends over the night (ex. saying maps have been >65 but decreasing overnight is much more useful than saying BPs have ranged between 90-120/40-80)
-Oxygenation with vent settings if relevant

Ins and outs

-Please use total UOP as well as net negative from the previous 24 hours (i.e. calendar day) to avoid confusion. Other attendings or fellows may have different preferences regarding this.
- If they were 2L negative, how did we achieve this? For example "He was net negative two liters yesterday on a Lasix gtt at 20mg and a dose of supplemental Diuril at 16:00"

Swan Numbers

-Please report most recent CVP or Swan numbers, including trends; mixed venous saturation and trend is crucial in filling pressures. Leave your interpretations for your cardiac assessment.

Exam

-Feel free to keep this super brief, definitely don't need to hit all the systems. If the patient is stable and the exam hasn't changed, you can say "unchanged".
-Comment on access sites and extremity exam after cath/IABP

Labs

-Trends are critical here, if relevant. If the creatinine is elevated, what was it compared to yesterday or the day before? If it is the patient's baseline, please say so.
1. Heme 8: WBC (and trend if relevant), Hgb (and trend), platelets

2. ABG or VBG or SVO2 trend, lactate trend
3. BMP: Relevant items in order. Creatinine is always relevant.
4. Coags (INR if on warfarin or if abnormal), if on heparin and therapeutic Xa, just say "therapeutic"
5. Culture updates

CXR/other imaging
-Please read this before rounds, should be pulled up by co-resident or intern. Always comment on position and presence of lines/tubes, ETT, etc.

EKG
-If new, please give a read.

Assessment and Plan
-Systems based, always starting with Cardiology first
-Be sure to give your assessment of what is actually going on, not just plan or list of medications

1. Cards
-Must include fluid assessment and fluid balance goal
-Please assess meaning of swan numbers (e.g. "continues to exhibit biventricular pressure overload with low cardiac output")
-If in shock, please name etiology (cardiogenic, mixed, distributive, hypovolemic, etc.)
-For heart failure patients, must comment on afterload (what is your MAP goal), pump function (do we need to wean or add inotropes), and preload (are they volume-up or volume down, what is your fluid goal for the day and how do you want to achieve it?)
-Address all drips and whether to continue, discontinue, or adjust
2. Pulm
-Must include plan for ventilator for the day if vented
3. ID
-Must include antibiotic days, indication, and intended duration
4. GI/Liver
-Must include daily nutrition plan
5. Renal
-Here you can comment on creatinine trend and it's meaning for the patient
6. Neuro
-Must always mention sedation plan (i.e. weaning) and overall goal on RASS
-Please comment on delirium and etiologic differential if present
7. Other systems that are relevant

Goals of Care/Code Status (this is the last item, but often most critical)
-Remind everyone on rounds if the patient is not full code
-Patients in the CICU often have some degree of cognitive or communicative impairment. They should still be involved in goals of care discussions to the fullest extent possible.
-Document all goals of care conversations in progress notes or separately. Listing surrogate decisions makers and their contact info if not available elsewhere in the EMR here is helpful.
-Most invasive procedures will involve a temporary reversal of code status for patients that are DNR. In addition, a patient's expected outcome can change significantly with anticipated/successful/cancelled procedures (TAVR, transplant, LVAD, ablation, etc). For some patients, getting through such a procedure may be the primary goal of their ICU stay. As such, please involve the fellow/attending (including procedural) in goals of care conversations involving patients awaiting or with recently completed procedures.
-Involve the fellow/attending (including procedural) when goals of care change from that discussed on rounds.

Checklist
-CICU policy to review remaining checklist Items (DVT ppx, lines/tubes and days, etc.)

CICU Rounding Document

Date:	Initials:	Admit Date:	Code Status:

A	**RASS**	**Current**	**Goal**	**Lines** CVC #1 _____ Need D/C CVC #2 _____ Need D/C HD _____ Need D/C Port _____ Need D/C PICC _____ Need D/C Arterial _____ Need D/C Foley _____ Need D/C ETT _____ Need D/C Chest Tube _____ Need D/C Drain _____ Need D/C
	PAIN			
B	**SAT Start Time**: _____ **Result**: Pass Fail **SBT Start Time:** _____ **Result**: Pass Fail **O_2 Settings:** _____ **Vent Correctly Ordered** __			
C	**Choice of Sedation** Continuous PRN NA			
D	**CAM** Positive Negative NA			
E	**Early Mobility** ROM Stand/Sit March/Walk			
F	**Family** Present Meeting Contact			**Medications:** Stress Prophy:_____ ABX:_____ DVT Prophy:_____ CHG:_____
G	**Glucose**		**Nutrition**	

DAILY GOALS

Hemodynamics

Normal Hemodynamics

RA<8
RV <30/8
PA 30/15 (20)
PCW <15
LA <15
LV 140/15
Ao < 140/90

HR 60-100
BP <140/90
CI 2.2-2.4
SVR 1200

Hemodynamic Profile of Shock States

Shock state	CVP	PCWP	CO	SVR
Hypovolemic	↓	↓	↓	↑
Cardiogenic	↑	↑	↓	↑
Obstructive				
Impaired diastolic filling	↑	↑	↓	↑
Impaired systolic contraction	↑	↓	↓	↑
Vasodilatory/distributive				
Pre-resuscitation	↓	↓	↓	↓
Post-resuscitation	↑	↑	↑	↓

Critical Care Equations

Cardiac Output = HR x Stroke Volume
MAP = (CO x SVR) + CVP or RAP
SVR = (MAP-CVP)/CO x 80
PVR = (mPA-PCWP)/CO x 80
Fick CO (L/min) = VO/ [(SaO – SvO) x Hb x 13.4]
Estimated VO_2 = 125 mL O_2/min x BSA
Coronary Perfusion = Aortic diastolic - LVEDP
Transpulmonary Gradient = mPA - PCWP (gradient > 12 mmHg suggests pulmonary hypertension)
PAPi = PAs-PAd / RA (normal >1.85)
RVSWI = (PA – RA) x CI/HR (normal 450 - 900)

Mechanical Ventilation in the CICU

Traditional Nasal Cannula

- Provides flow of up to 6 liters/minute

High Flow Nasal Cannula

- Heated and humidified
- Provides flow of up to 60 liters/minute
- Able to provide ~7 cmH_2O of PEEP

Non-Invasive Positive Pressure Ventilation

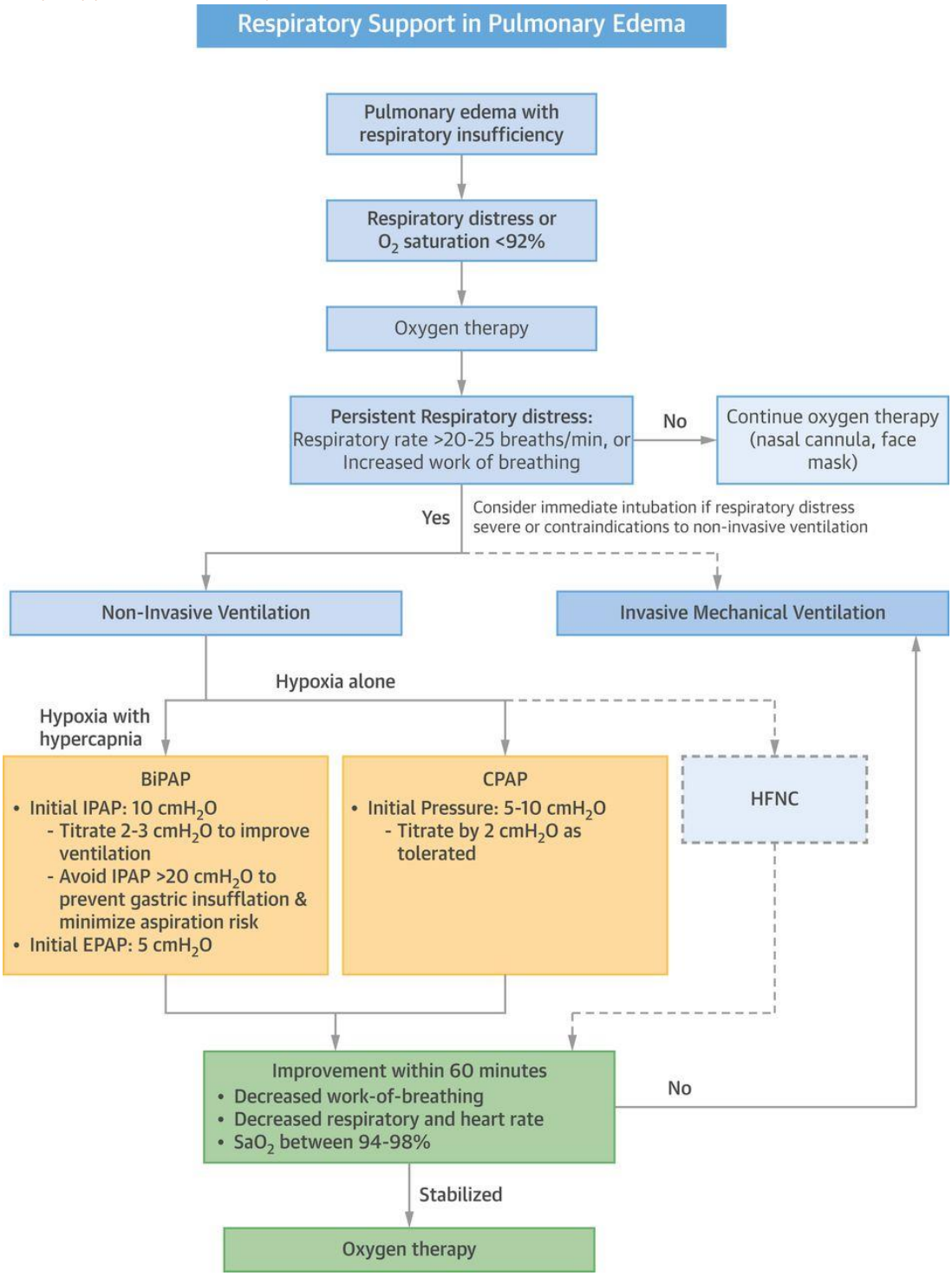
- Includes continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP)
- If pure hypoxia is the issue, utilize CPAP
- If hypoxia and hypercarbia are both present, utilize BiPAP
    - BiPAP provides a separately titratable inspiratory positive airway pressure (IPAP) and expiratory positive airway pressure (EPAP)
    - BiPAP can reduce work of breathing, increase tidal volumes more than CPAP, and improve ventilation in patients with hypercarbia
- Patient selection is important. Contraindications:
    - Concern about ability to protect airway (ex. altered mental status or apnea)
    - Facial deformities
    - Concern for aspiration, active emesis, or inability to control secretions
    - Recent upper airway or GI surgery

Invasive Mechanical Ventilation

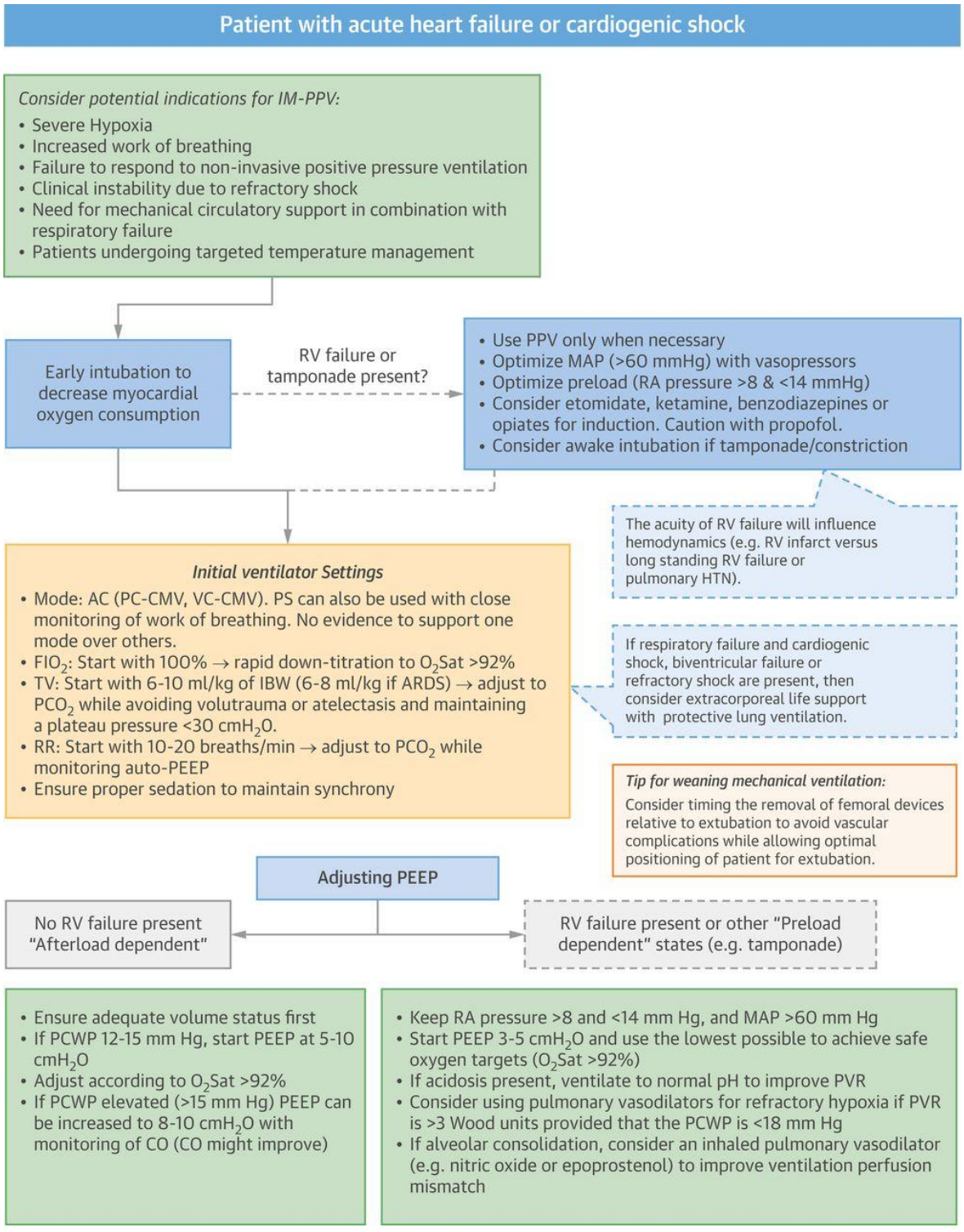
- Indications: refractory hypoxia or hypercarbia, unsustainable work-of-breathing, and need for airway protection in the setting of altered mental status, cardiorespiratory arrest, impending hemodynamic/ respiratory collapse, active vomiting, or upper gastrointestinal bleeding.
- All patients on mechanical ventilation should receive lung protect ventilation (ex. TV less than 6 cc/kg of ideal body weight)
- PEEP setting depends on whether or not the patient is afterload or preload dependent

No RV Failure Present "Afterload dependent"	**RV failure present or other "Preload dependent" states (e.g. tamponade)**
• Ensure adequate volume status first • If PCWP 12-15 mm Hg, start PEEP at 5-10 cmH_2O • Adjust according to O_2Sat >92% • If PCWP elevated (>15 mm Hg) PEEP can be increased to 8-10 cmH_2O with monitoring of CO (CO might improve)	• Keep RA pressure >8 and <14 mm Hg, and MAP >60 mm Hg • Start PEEP 3-5 cmH_2O and use the lowest possible to achieve safe oxygen targets (O_2Sat >92%) • If acidosis present, ventilate to normal pH to improve PVR • Consider using pulmonary vasodilators for refractory hypoxia if PVR is >3 Wood units provided that the PCWP is <18 mm Hg • If alveolar consolidation, consider an inhaled pulmonary vasodilator (e.g. nitric oxide or epoprostenol) to improve ventilation perfusion mismatch

Respiratory Support in Pulmonary Edema



Respiratory Support in Cardiogenic Shock



Common CICU Medications

Vasopressor, Inotrope, and Vasodilator Properties

	Dopa	α_1	β_1	β_2	Other	HR	CVP	CO	SVR	PVR
Vasopressors										
Dopamine	+++++	+++	++++	++		↑	↔	↑	↔ or ↑	↔ or ↑
Epinephrine		++++	++++	+++		↑	↔	↑	↑	↑
Norepinephrine		+++++	+++	++		↑	↔	↑	↑	↑
Phenylephrine		+++++				↔ or ↓	↔	↑	↑	↑
Vasopressin	N/A				V_1 and V_2 agonism	↔ or ↓	↔	↔ or ↓	↑	↔ or ↓
Inotropes										
Dobutamine		+	++++	++		↑	↔	↑	↔ or ↓	↔ or ↓
Isoproterenol			+++++	+++++		↑	↔	↑	↔ or ↓	↔ or ↓
Milrinone	N/A				PDE_3 inhibition	↔ or ↑	↔	↑	↓	↓
Vasodilators										
Nitroglycerin					cGMP	↔ or ↑	↔ or ↓	↔ or ↑	↔ or ↓	↔ or ↓
Nitroprusside					cGMP	↔ or ↑	↔ or ↓	↔ or ↑	↔ or ↓	↓

cAMP=cyclic adenosine monophosphate; cGMP=cyclic guanosine monophosphate; N/A=not applicable; PDE3=phosphodiesterase type 3

Vasopressors

	Dopamine	Epinephrine	Norepinephrine	Phenylephrine	Vasopressin
Starting dose/titration	Start: 2-5 mcg/kg/min Titrate: 1-5 mcg/kg/min every 1 minute	Start: 0.01 mcg/kg/min Titrate: 0.01-0.2 mcg/kg/min every 1 minute	Start: 0.1 mcg/kg/min Titrate: 0.01-0.2 mcg/kg/min every 1 minute	Start: 50-100 mcg/min Titrate: 20-50 mcg/min every 1 minute	Start: 0.01-0.03 units/min
Maximum dose	20 mcg/kg/min	1 mcg/kg/min	1 mcg/kg/min	300 mcg/min	0.06 units/min for sepsis or 0.08 units/min for cardiac

Inotropes

	Dobutamine	Milrinone	Isoproterenol
Daily cost*	$24.74	$54.77	$12,978
Starting dose/titration	Start: 1-2.5 mcg/kg/min Titrate: 2.5 mcg/kg/min every 5 minutes	Start: 0.125-0.25 mcg/kg/min	Start: 0.5 mcg/min
Maximum dose	20 mcg/kg/min	0.75 mcg/kg/min	10 mcg/min
Comments		May cause more hypotension than dobutamine due to potent vasodilating effects 90% renally cleared	Alternative agents for bradycardia should be trialed first due to cost
*dose calculated for a 70 kg patient using highest dose in given dosage range for a 24-hour period unless otherwise specified			

Vasodilators

	Nitroprusside	Nitroglycerin
Daily cost*	$786	$15
Starting dose/titration	Start: 0.2-0.5 mcg/kg/min Titrate: 0.2-0.5 mcg/kg/min every 2 minutes	Start: 5-10 mcg/min Titrate: 5-10 mcg/min every 2 minutes
Maximum dose	10 mcg/kg/min	200 mcg/min
Comments	Monitor thiocyanate levels every 48-72 hours Thiocyanate levels are NOT analyzed on weekends	

Oral afterload options	Hydralazine and isosorbide dinitrate or captopril (stable renal function)
	• Oral afterload can be uptitrated with each dose
	• Hydralazine
	  ○ Starting dose 10mg TID (maximum of 100mg TID)
	• Isosorbide dinitrate
	  ○ Starting dose 10mg TID (maximum of 40mg TID) – order without nitrate free interval
	• Captopril
	  ○ Starting dose of 3.125mg TID (maximum of 50mg TID)	

*dose calculated for a 70 kg patient using highest dose in given dosage range for a 24-hour period unless otherwise specified		

Diuretics

	Furosemide	Bumetanide	Torsemide	Metolazone	HCTZ	Chlorothiazide
Daily cost	40mg=$0.04	1mg=$0.80 IV=$1.71	20mg=$0.07	5mg=$1.38	25mg=$0.04	500mg=$33
Onset (peak effect)	30-60 min PO 5 min IV (2 hours)	30-60 min PO 2-3 min IV (1-2 hr)	1 hr PO (1-2 hr)	2-3 hr (6-8 hr)	2 hr (4 hr)	2 hr (3-6 hr)
Duration of action	4-6 hr	4-6 hr	6-8 hr	12-24 hr	5-15 hr	6-12 hr
IV to PO conversion	1:2	1:1	1:1	N/A	N/A	N/A
Comments	Loop diuretic equivalents: bumetanide 1mg=torsemide 20mg= furosemide 40mg PO Thiazide diuretic equivalents: 250mg chlorothiazide=2.5mg metolazone Chlorothiazide is restricted to: 1. Pediatrics (>18 years of age) 2. Adult patients: chlorothiazide intravenous (Diuril®) is restricted to patients with inadequate diuresis after receiving at least one appropriate dose of IV furosemide or equivalent (intermittent furosemide >160 mg/dose or furosemide infusion >960 mg/24 hours) AND • Inadequate diuresis from oral thiazide diuretic (metolazone >5 mg) OR NPO status (cannot administer an oral thiazide diuretic)					

IV Antihypertensives

	Clevidipine	Nicardipine	Nitroprusside
Daily cost*	$964	$1649	$786
Starting dose/titration	Start: 1-2 mg/hour Titrate: 1-2 mg/hour every 90 seconds by doubling the dose	Start: 2.5-5 mg/hour Titrate: 2.5 mg/hour every 15 minutes	Start: 0.2-0.5 mcg/kg/min Titrate: 0.2-0.5 mcg/kg/min every 2 minutes
Maximum dose	16 mg/hour	15 mg/hour	10 mcg/kg/min
Comments	Daily limit of 1000mL due to lipid content Need to take into consideration lipid content if receiving concomitant propofol		Monitor thiocyanate levels every 48-72 hours Thiocyanate levels are NOT analyzed on weekends
*dose calculated for a 70 kg patient using highest dose in given dosage range for a 24-hour period unless otherwise specified			

Rate Control

	Esmolol	Diltiazem	Metoprolol	Digoxin
Daily cost*	$2781	$15	<$5	<$5
Starting dose/titration	Start: 25-50 mcg/kg/min Titrate: 25-50 mcg/kg/min every 2 minutes	Load: 5-20 mg Start: 5 mg/hour Titrate: 2.5-5 mg/hour every 30 minutes	Start: 2.5 to 5 mg IV bolus; repeat every 2 to 5 minutes up to 3 doses	Load: up to 1000 mcg (administered as separate doses)** Maintenance: start at 125 mcg or 250 mcg PO daily
Maximum dose	300 mcg/kg/min	15 mg/hour	15 mg (cumulative dose over a 10 to 15 minute period)	Doses titrated based on steady-state levels
Comments	Caution with volume – a 70kg pt on max dose would provide ~1.5 L/day	Avoid in patients with HFrEF		Digoxin level may be checked after 5-7 days of maintenance dosing or after initial loading dose Level should be at least 6-8 hours after digoxin dose

*dose calculated for a 70 kg patient using highest dose in given dosage range for a 24-hour period unless otherwise specified
**Can be given IV or PO, 50% of the dose should be administered initially with the remaining portion as 25% fractions at 6-8 hour intervals. Dose may need to be adjusted for renal impairment and drug interactions (ex. amidoarone)

Antiarrhythmics

	Amiodarone	Lidocaine	Procainamide
Starting dose/titration	Load: 300 mg rapid IVP for pulseless VT 150 mg over 10 minutes for VT with a pulse or A-Fib (may repeat x1) Start: 1 mg/min for 6 hours followed by 0.5 mg/min for 18 hours	Load: 1-1.5 mg/kg – may repeat in 5 minutes Start: 0.5 mg/min	Load: 15-18 mg/kg over 25-30 min or 100-200 mg repeated every 5 minutes as needed to a total dose of 1 gram Start: 1 mg/min
Maximum dose	1 mg/min	4 mg/min	4 mg/min
Comments	1:2 IV to PO conversion is typically used to calculate PO equivalents Can be run for 24 hours in peripheral line Typically load with 400mg BID or 400mg TID after 24 hours of IV for a total of 10g	Monitor serum lidocaine levels 12-24 hours after initiation (goal 1.5-5 mg/L)	Used for refractory VT or in patients with WPW Reduce loading dose to 12 mg/kg in severe renal or cardiac impairment

$P2Y_{12}$ Antagonists

	Clopidogrel	Prasugrel	Ticagrelor
Loading dose	300mg or 600mg	60mg	180mg
Maintenance dose	75mg QD	10mg QD	90mg BID
% platelet inhibition	30 – 40	60 – 70	60 – 70
Recommended holding prior to CABG	5 days	7 days	5 days
Comments	Preferred agent by ACC/AHA guidelines for those receiving triple therapy (ASA, $P2Y_{12}$ antagonist, and anticoagulation)	Need to check insurance coverage Black box warning against use in patients with a history of stroke or TIA Warning of use in patients >75 years or <60 kg	Need to check insurance coverage Potential for adenosine-induced bradycardia and dyspnea
Switching $P2Y_{12}$ agents during acute phase	To prasugrel: 60mg LD (irrespective of timing and dosing of clopidogrel) To ticagrelor: 180mg LD (irrespective of timing and dosing of clopidogrel)	To clopidogrel: 300mg or 600mg LD (24 hours after last prasugrel dose) To ticagrelor: 180mg LD (24 hours after last prasugrel dose)	To clopidogrel: 300mg or 600mg LD (12 hours after last ticagrelor dose) To prasugrel: 60mg LD (12 hours after last ticagrelor dose)

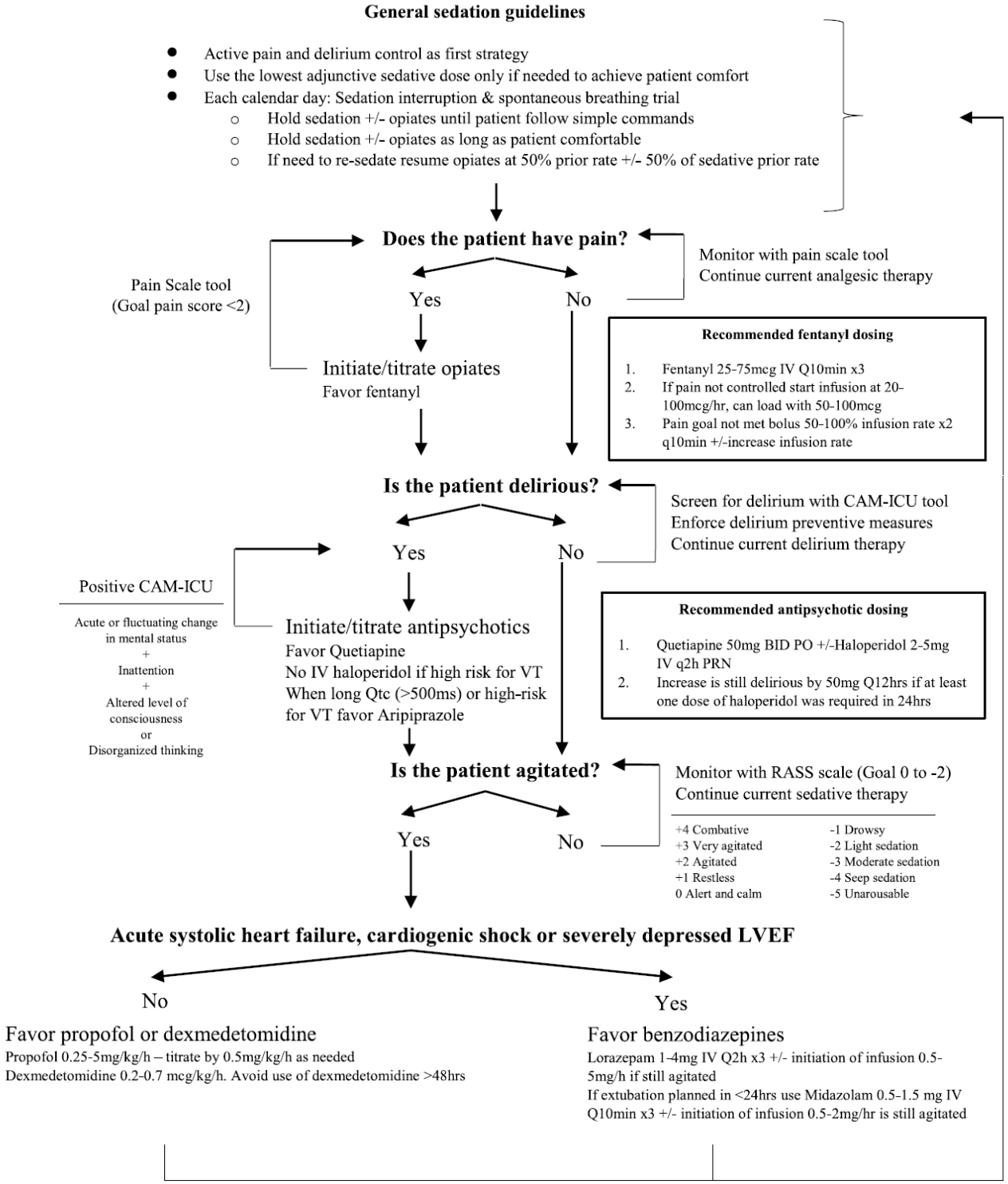
Sedation

Hemodynamic and Cardiac Effects of Antipsychotic and Sedative Agents

Agent	Preload	Afterload	HR	Cardiac contractility	CO	Coronary flow	Coronary vascular resistance	Myocardial oxygen consumption	Myocardial lactate production	VT-threshold
Opioids	↓	↓	↓	=	=	=	=	=	=	↑
Antipsychotics	=or↓	↓or↑	=or↑	=	↑			↓		↓
Propofol	↓	↓↓	↓	=or↓	↓↓	↓	↑	↓	=or↑	↑
Benzodiazepines	↓	↓	=or↓	=	=	=or↑	=	↓	=	=or↑
Dexmedetomidine	=	↓or↑	↓	↓	↓	↓	↑	=or↓	=	↑

CO: cardiac output; HR: heart rate; VT: ventricular tachycardia.

Proposed Sedation Algorithm in the Critically Ill Cardiovascular Patient



Pulmonary Artery ("Swan-Ganz") Catheterization

Indications

- Unexplained or unknown volume status in shock
- Severe cardiogenic shock
- Suspected or known pulmonary hypertension
- Patients listed for heart transplantation are required to have a leave-in Swan

Absolute and Relative Contraindications

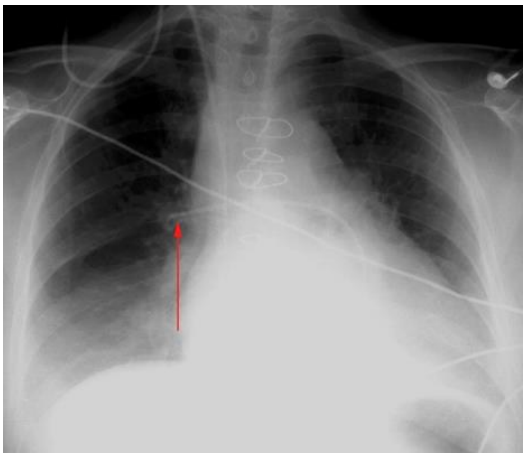
- Absolute: infection at insertion site
- Relative (safer to place under fluoroscopy in these situations):
    - Coagulopathy, thrombocytopenia
    - Patients with severe pulmonary hypertension are considered higher risk due to the risk of pulmonary artery rupture
    - Patient with an underlying RBBB or LBBB (risk of complete heart block)
    - Patient with a newly placed defibrillator or pacemaker (risk of lead dislodgement)
    - History of difficulty with prior procedures due to abnormal neck/vascular anatomy or large RV

Complications

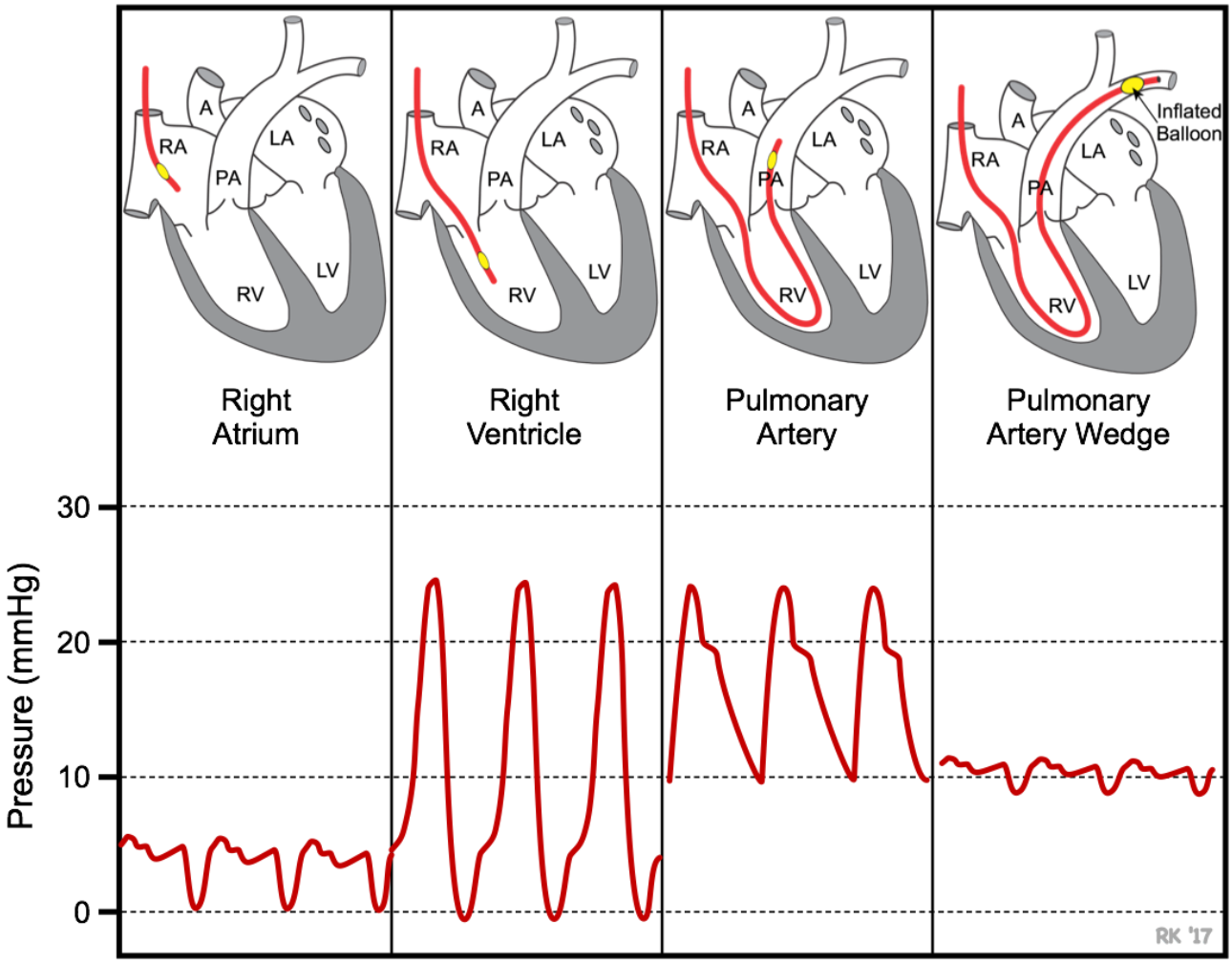
- Tip of the catheter may fall in to the right ventricle. This can precipitate ventricular tachycardia. Suspect this if the patient is having more ventricular ectopy. Confirm with a CXR and ask the fellow to reposition the Swan.
- The tip of the catheter may jump forward into the pulmonary artery. This is called "perma-wedge". This results in obstruction of flow in the PA. The most catastrophic complication of this would be pulmonary artery rupture. Perma-wedge is identified when there is a dampened PA waveform. Notify the CICU fellow and they will pull back the Swan.

Monitoring

- Obtain a daily CXR
- The tip should curve into main pulmonary artery, but not more peripheral than the junction between the medial and middle 1/3rd of the ipsilateral lung field in West Zone 3 (below the level of the left atrium).



Waveforms



Intra-Aortic Balloon Pump

Indications

- Hemodynamically unstable cardiogenic shock (STEMI, acute MR, VSD)
- Refractory angina in UA/NSTEMI/STEMI
- High risk PCI or CABG
- Bridge to transplant
- VT storm

Contraindications

- Aortic dissection, AAA/TAA
- Severe PAD, limb ischemia, aortic/peripheral grafts (relative)
- Moderate/severe AI
- Coagulopathy or uncontrolled bleeding
- Sepsis

Complications

- Hemolysis, thrombocytopenia
- Infection
- Vascular injury: thrombosis, ischemia, embolism, dissection, bleeding, renal failure

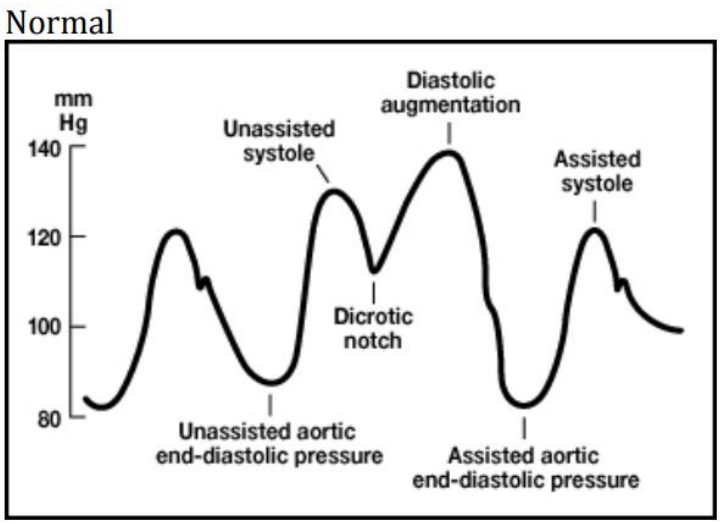
Mechanism

- Deflates in systole → afterload reduction → increase CO by 20% (0.5-1 L/min) + decrease in LV wall stress and O_2 demand
- Inflates in diastole → augments coronary perfusion
- Trigger: ECG, fiber optic manometer, transduce manometer
- Consider: Trigger, timing, position, size, kink in tubing

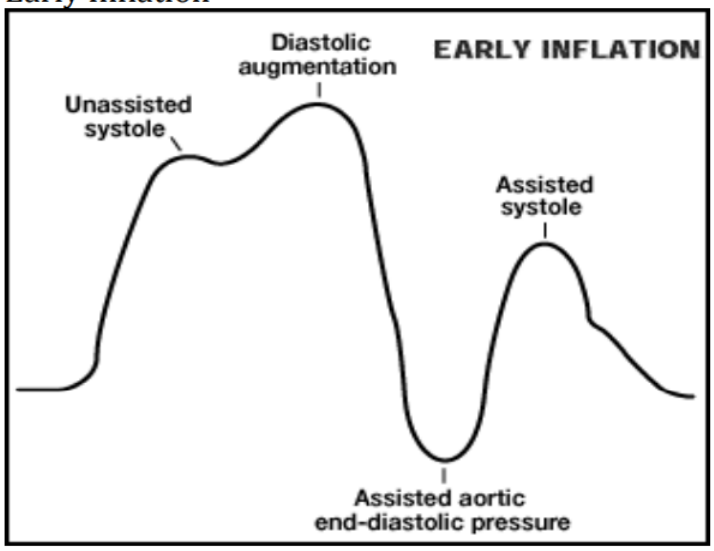
Monitoring

Order the "GEN Intra-Aortic Balloon Pump Management" order set
Serial distal pulses, daily CXR (Ao knob/1-2cm above carina. 2-3rd intercostal)
Patient must remain on bedrest with HOB no > 30 degrees; restrict hip flexion

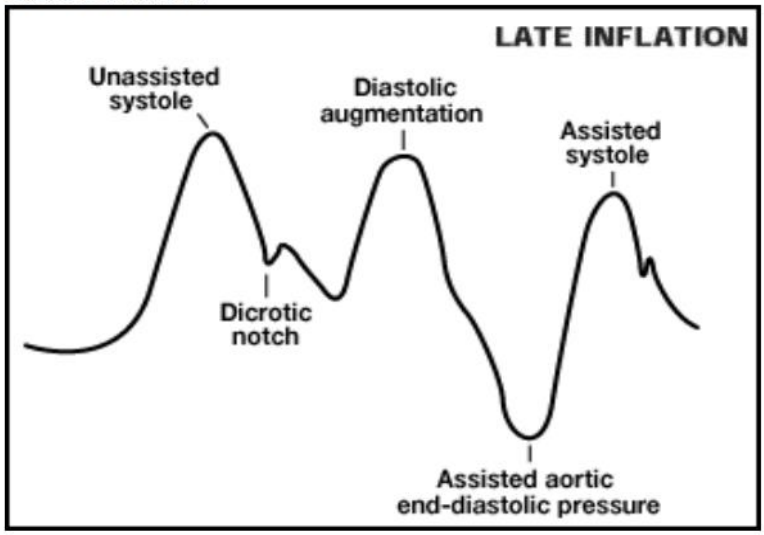
Timing



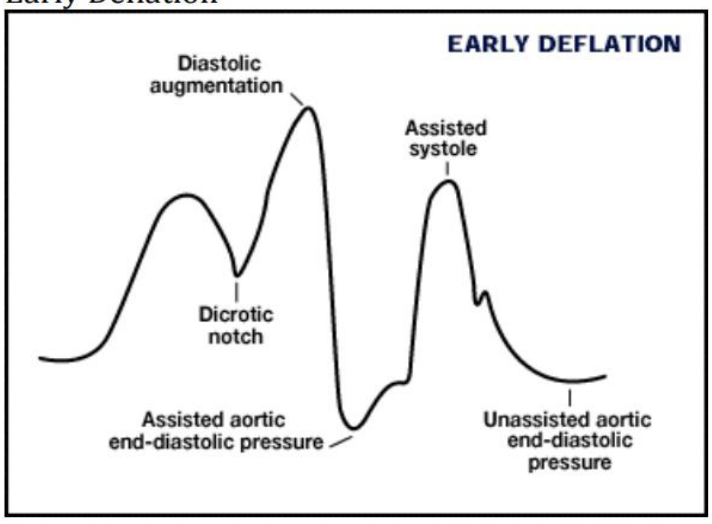
Early Inflation



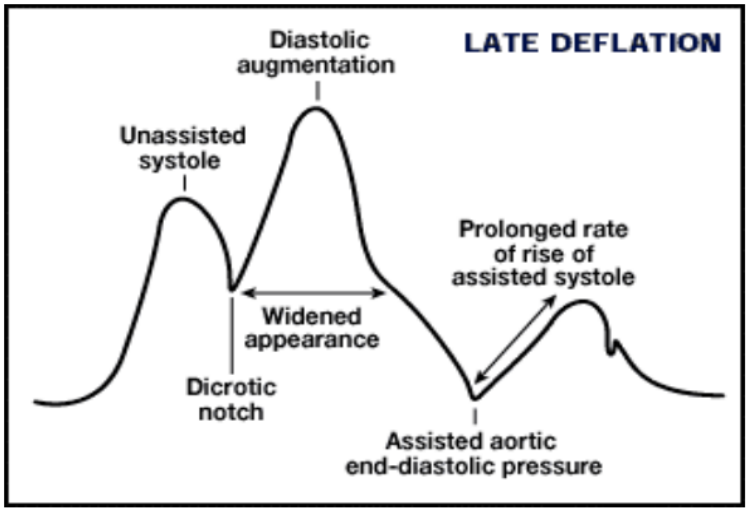
Late Inflation

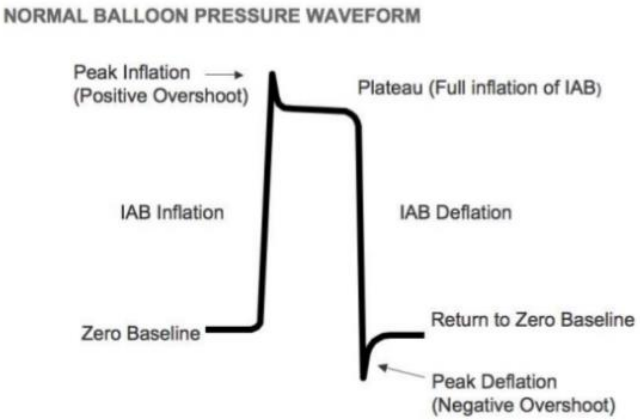


Early Deflation

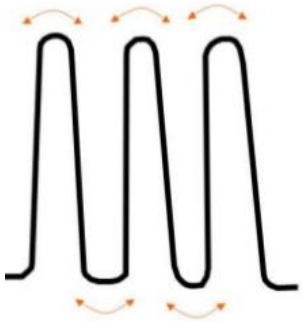


Late Deflation





Catheter Kink



Impella

Indications

- Very high-risk PCI (patients with severe multi-vessel CAD)
- Complications of AMI including cardiogenic shock
- Stabilization of advanced heart failure as a bridge to decision regarding durable advanced therapies
- Patients with refractory arrhythmias associated with ischemia

Contraindications

- Aortic regurgitation or mechanical aortic valve
- Aortic aneurysm or dissection
- Severe aortic or peripheral arterial disease
- LV or left atrial thrombi
- Bleeding diathesis
- Sepsis

Mechanism

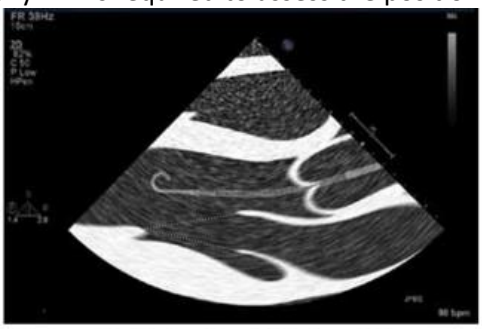
- The Impella is an axial flow pump that is inserted retrogradely across the aortic valve into the left ventricle. The pump revolves a high speed and draws blood out of the left ventricle and ejects it proximally into the ascending aorta. May increase cardiac output by anywhere from 2.5 to 5 liters per minute.
- Performance levels range from P0 to P9. Determines the number of times the pump rotates per minute and the rate of blood flow. Adjust performance levels based on pulmonary artery catheter readings.

Complications

- Limb ischemia
- Bleeding or hematoma at access site
- Hemolysis
- Device failure or migration

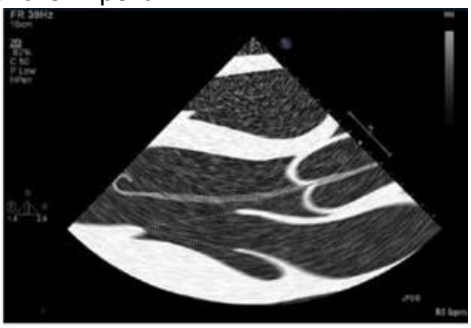
Monitoring

- A daily TTE is required to assess the position of the Impella.



3A. Correct Positioning of Impella® Catheter (TTE)

- Catheter inlet area about 4–4.5 cm below the aortic valve
- Catheter outlet area well above the aortic valve
- Catheter angled toward the left ventricular apex away from the heart wall and not curled up or blocking the mitral valve



3B. Impella® Catheter too far into the left ventricle (TTE)

- Catheter inlet area more than 4 cm below the aortic valve
- Catheter outlet area across or near the aortic valve
- Catheter too close to the heart wall or mitral valve

- Obtain daily CBC and coagulation studies to assess for hemolysis
- If a patient codes with an Impella in place, turn down the performance level to 2 and start chest compressions.

Targeted Temperature Management and Induced Hypothermia

Indications and temperature goals

Indication	Time until initiation	Cooling	Duration of cooling
- Unconscious after ROSC with no purposeful movement to verbal command - Arrest to ROSC < 60 min - SBP >100 or MAP >60 (vasopressors/IABP permitted)	Within 4-6 hours	Goal of achieving target cooling temperature (36°C) within 3 hours of initiation	24 hours after achieving target temperature

Temperature goal	Comments
Maintenance of normothermia (35-36°C)	• Target is above shivering threshold: ○ Neuromuscular blockade (NMB) will likely not be needed ○ Can limit sedation and analgesia if needed ○ Pharmacokinetics and pharmacodynamics minimally affected ○ Hemodynamics likely not affected by the target temperature (may be able to consider other anti-shivering agents usually otherwise limited by hemodynamic consequences)
Induced hypothermia (32-34°C)	• Target is largely below shivering threshold ○ NMB not usually needed ○ Can limit sedation and analgesia if needed ○ Pharmacokinetics and pharmacodynamics considerably affected ○ Hemodynamics likely affected by target temperature (especially heart rate)

*For patients with cardiac arrest there is no difference in outcomes between normothermia and hypothermia. Normothermia should be considered in those patients for whom lower temperatures convey risk, including:

- Temperature <30°C (86°F) after cardiac arrest
- Pregnancy
- Systemic infection/sepsis
- Major surgery within 14 days
- Active ongoing bleeding
- Known bleeding predisposition

Goal: sustain cooling for at least 24 hours

Phase I: Cooling

Goal of achieving target cooling temperature within 3 hours (or less) of initiation:

- Cool to established core body temperature goal: normothermia: 35-36°C or hypothermia: 32-34°C
  - Avoid overcooling (core body temperature <32°C)
  - Ensure sedation and analgesia goals are met: RASS -4, pain goal 0
  - Prevent fever with prophylactic anti-shivering medications
  - If unable to achieve targeted temperature goal within 3 hours, obtain secondary temperature. Notify house officer if secondary temperature also not within targeted temperature goal.

Other Cooling Device Considerations

- Decrease heated-wire circuit temperature on ventilator
- Discontinue warming on CRRT system if in use
- If patient is supported with ECMO, utilize ECLS to modulate temperature changes per protocol goals

Prevent and Treat Shivering

- Use the medications below to prevent shivering:
  - Acetaminophen 650mg PO/NG/PR Q6H x4 (hold if acute liver injury)
  - Buspirone 30mg PO/NG Q8H x3
  - Dexmedetomidine per target RASS goal
  - Magnesium 2g IVPB Q8H (hold if Mg >4 mg/dL) x3
- Sedation:
  - Fentanyl IV continuous infusion plus midazolam infusion or propofol
  - Dexmedetomidine can be used to lighten sedation or facilitate extubation towards the end of protocol

- Do not paralyze with NMB unless shivering occurs despite adequate sedation
  - If patient arrives on floor with NMB ordered, this should be discontinued
  - To treat shivering see **algorithm 1**

Establish Continuous Temperature Monitoring

- Sites include: bladder, esophageal, pulmonary, rectal
- Monitor temperature continuously and document every 30 minutes during active cooling and rewarming, and every hour during maintenance phase

Labs/Blood Gases

- If not already checked, collect:
  - CMP with Mg
  - Troponin
  - CBC
  - PT/PTT
  - INR
  - Blood gas
  - Accu-check

Other

- Consider arterial line for close hemodynamic monitoring
- CT head at start of cooling or ASAP
- Place nasogastric or orogastric tube
- Continuous EEG if utilizing neuromuscular blockade

Phase II: Maintenance

Arrhythmias

- Monitor patient for arrhythmias associated with hypothermia
  - If persistent, life-threatening dysrhythmias, hemodynamic instability, or bleeding develops, discontinue cooling, and ensure that the patient is actively re-warmed
  - Heart rates ≤40 BPM are frequent and are not alone a cause for concern in the absence of other evidence of hemodynamic instability

Continue Shivering Prevention and Maintain Sedation/Analgesia

Labs/Blood Gases

- Every 6 hours obtain:
  - CMP
  - Mg
  - Blood gas
- Potassium goal: 4-5 mEq/L: treat potassium values <4 mEq/L with IV administration of K while the patient is being cooled. Note that K shifts intracellularly during the cooling.
- Glucose should be kept at target range of 144-180 mg/dL and treated with insulin if elevated
- ICU electrolyte protocol should NOT be ordered during initiation, maintenance, or rewarming phases of therapy

Nutrition

- At this time, there is insufficient evidence to make recommendations on nutrition during initiation, maintenance, or rewarming phases of therapy

Phase III: Transition to Rewarming and Controlled Rewarming

Temperature Control After Rewarming

- Fevers should be treated actively during and after rewarming
- Use acetaminophen and consider keeping cooling device in place in order to maintain temperature of 37°C for a minimum of 24 hours and up to 48 hours after rewarming

Provide Controlled Rewarming

- Begin rewarming 24 hours after obtaining goal temperature
- The goal of rewarming is normothermia without fever
- Patient should be rewarmed at a rate of 0.25°C per hour until normothermic (rewarming should be stopped at this point to avoid iatrogenic fever)

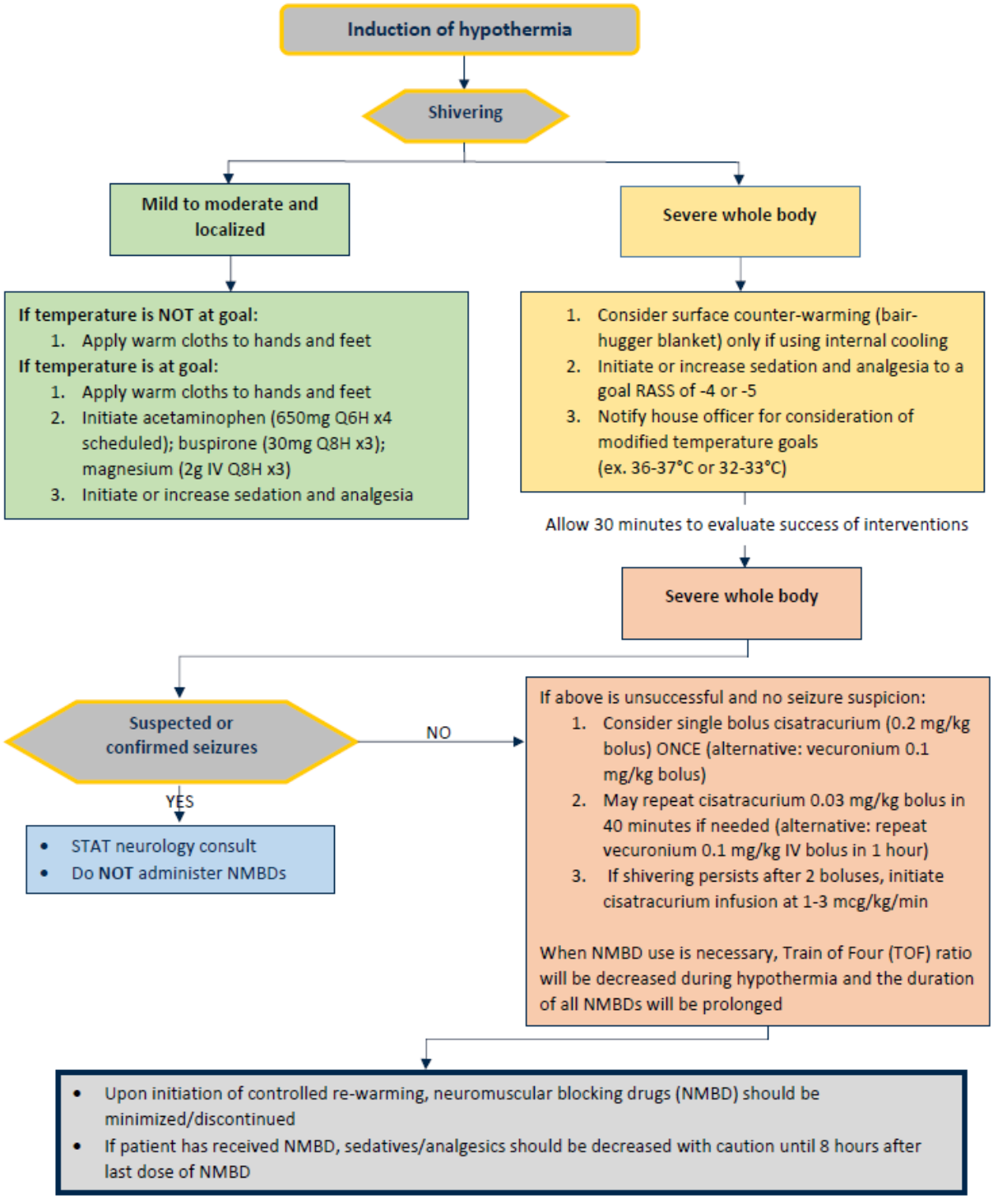
Medications During Rewarming

- Maintain sedation until a temperature of 35°C (95°F) is reached
- If a patient has received a NMB, discontinue before the sedative/analgesic agents
- If no NMB has been used, sedation and analgesia may be minimized/discontinued upon rewarming

Labs/Blood Gases

- Do not aggressively replace potassium as hyperkalemia can commonly occur during controlled rewarming as K shifts back extracellularly. Stop repleting K 8 h prior to rewarming.
- At 32 hours, obtain:
  - CMP
  - Mg

Algorithm 1: Overcoming Shivering During Induced Hypothermia



Notes

Notes

Notes

Notes