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Anesthetic management of patients with pulmonary hypertension and right ventricular failure for non-cardiac surgery

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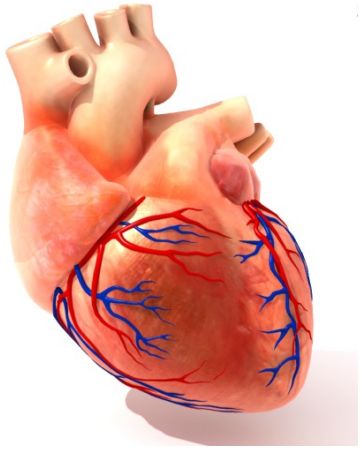
25/10/2025
Symposium GIAL, Lausanne



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ISHLT consensus statement: Perioperative management of patients with pulmonary hypertension and right heart failure undergoing surgery

Dana P. McGlothlin, MD [a] · John Granton, MD [b] · Walter Klepetko, MD [c] · ... · Warren Zuckerman, MD [jj] · Andreas Zuckermann, MD [c] · Teresa De Marco, MD [cc] ... Show more

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Special Article

CARDIOVASCULAR

Perioperative management of patients with pulmonary hypertension undergoing non-cardiothoracic, non-obstetric surgery: a systematic review and expert consensus statement

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Introduction

- In patients with pulmonary hypertension:
  - 30 days mortality after elective surgery: 2-18%
  - 30 days mortality after emergency surgery: 15-50%
  - Complication and mortality mainly due to RV failure
  - Adequate risk stratification and a tailored-individualised perioperative plan is paramount

Plan of presentation

- Clinical case
- Definition of pulmonary hypertension
  - Subtypes
  - Hemodynamic values
- Risk assessment
- Pathophysiology of intra op RV failure
- Anesthetic management
  - Monitoring
  - Swan

E1 overnight 

Called for emergency endoscopy for upper GI bleed.

76 year old M with rheumatoid arthritis, group I pulmonary HTN, gallstone pancreatitis s/p ERCP 1 day prior with melena and hypotension.

PMH

 # GI bleed – Hypotension with MAPs in the 40s, with multiple melanotic stools, received 4RBC, 1FFP, 1PLT, and now on Norepinephrine drip with MAP in the 60s. ICU triage placed 16g PIV and arterial line.

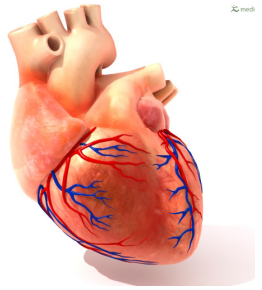
 # Pulmonary hypertension – On 3L NC at home, meds include Bosentan, Sildenafil, and IV Epoprostenol.

 # Gallstone pancreatitis – ERCP 1 day prior with sphincterotomy, stent placement (under MAC).

E1 overnight

Called for emergency endoscopy for upper GI bleed.

76-year-old M with rheumatoid arthritis, group I pulmonary HTN, gallstone pancreatitis s/p ERCP 1 day prior with melena and hypotension.



Recent TTE:

1. LV size small, hyperdynamic, EF 70-75%.
2. RV volume is severely increased with RV function moderately decreased.
3. Mild- Moderate TR, other valves unremarkable.
4. PASP 82 mmHg based on RAP 8 mmHg (SBP 88/56).

E1 overnight

Called for emergency endoscopy for upper GI bleed.

76-year-old M with rheumatoid arthritis, group I pulmonary HTN, gallstone pancreatitis s/p ERCP 1 day prior with melena and hypotension.

Vitals:

Sat: 97% on 6L NC

HR: 100 bpm

BP: 89/37

RR: 20 breaths/min

Exam:

Gen: Cachectic male, laying in bed, alert & oriented

Cardiac: Tachycardic

Pulm: Normal

Abdomen: Soft, non-tender

Airway: MP II, easy intubation in past

E1 overnight

Called for emergency endoscopy for upper GI bleed.

76-year-old M with rheumatoid arthritis, group I pulmonary HTN, gallstone pancreatitis s/p ERCP 1 day prior with melena and hypotension. **The proceduralist is requesting GA.**

How would you induce this patient for GA?
What additional medication would you like to have readily available ?
What monitoring would you want?

Pulmonary Hypertension

- High blood pressure within the arteries of the lungs.
- Definition: **Mean pulmonary artery pressure greater than 20 mmHg.**
  - Based on normal mean PA pressure of 14 mmHg

Pulmonary Hypertension

WHO Groups

- Group 1 – Pulmonary arterial hypertension (PAH)
- Group 2 – PH due to left heart disease
- Group 3 – PH due to chronic lung disease and/or hypoxemia
- Group 4 – PH due to pulmonary artery obstructions
- Group 5 – PH due to unclear multifactorial mechanisms

Pulmonary Hypertension

TABLE 1 Haemodynamic definitions of pulmonary hypertension (PH)

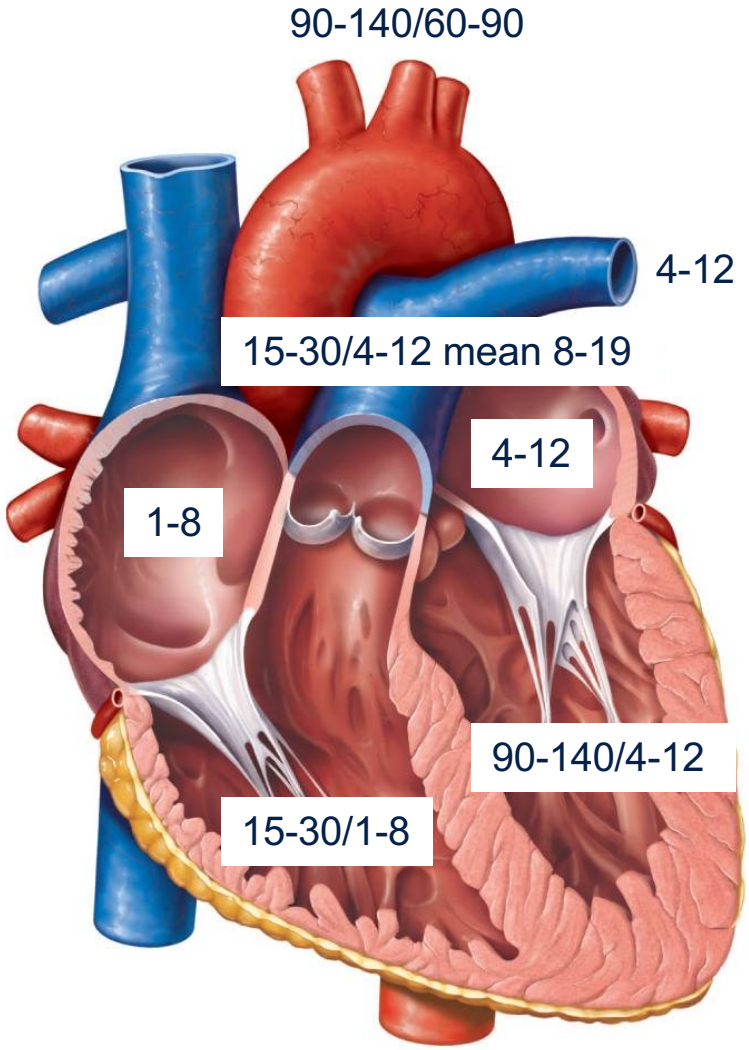
Definitions	Characteristics	Clinical groups[#]
Pre-capillary PH	mPAP >20 mmHg PAWP ⩽15 mmHg PVR ⩾3 WU	1, 3, 4 and 5
Isolated post-capillary PH (IpcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR <3 WU	2 and 5
Combined pre- and post-capillary PH (CpcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR ⩾3 WU	2 and 5

mPAP: mean puln ge pressure; PVR: pulmonary vascular resistanc eft heart disease; group 3: PH due to lung diseas bstructions; group 5: PH with unclear and/or mu

$$PVR = \left(\frac{PAP - PAWP}{CO} \right) \times 80$$

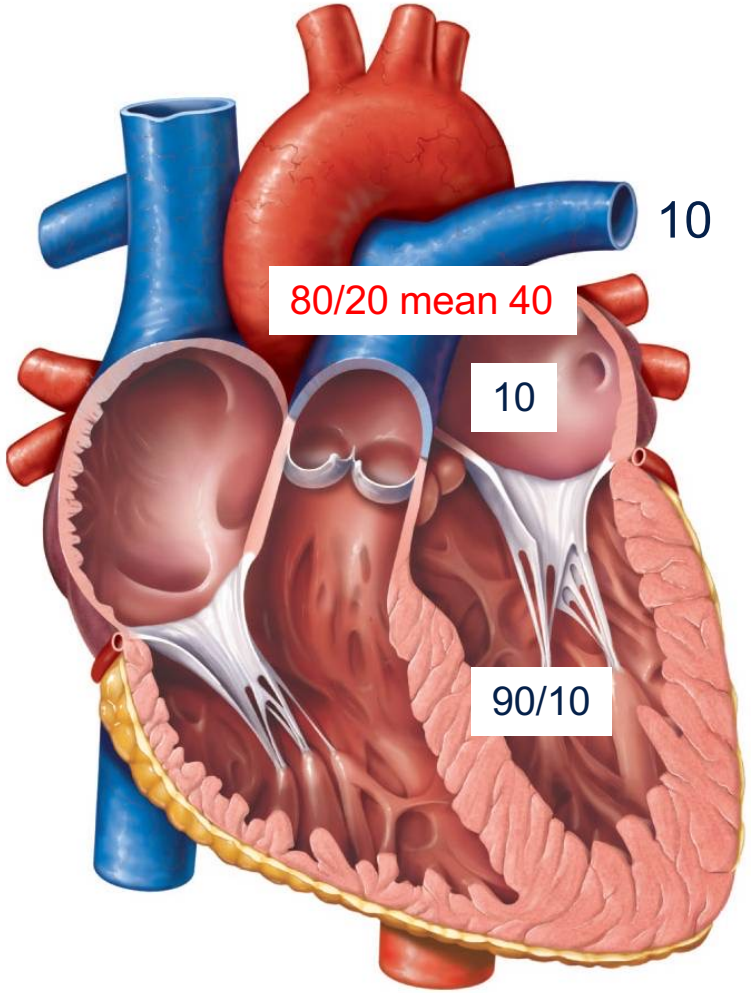
Simmonneau G, Montani D et al.. *Eur Respir J*. 2019; 53: 1801913.

Normal Hemodynamics



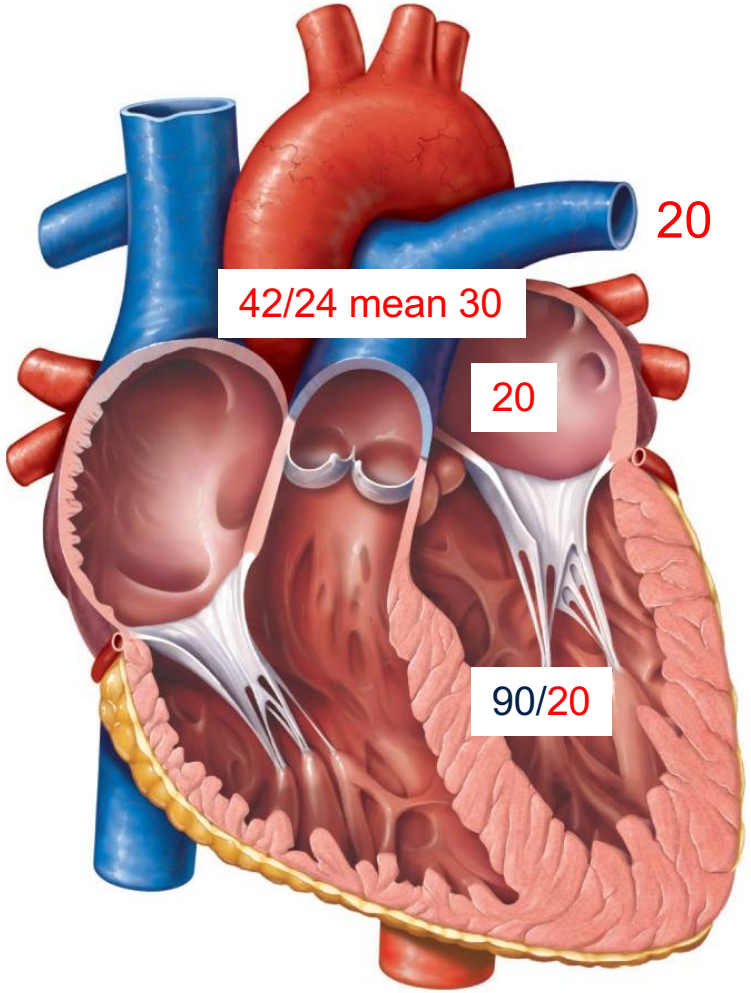
Kennedy, J. “Pulmonary Hypertension and Right Heart Failure”. Dec. 5, 2019.

(Pre-Capillary) Pulmonary Hypertension



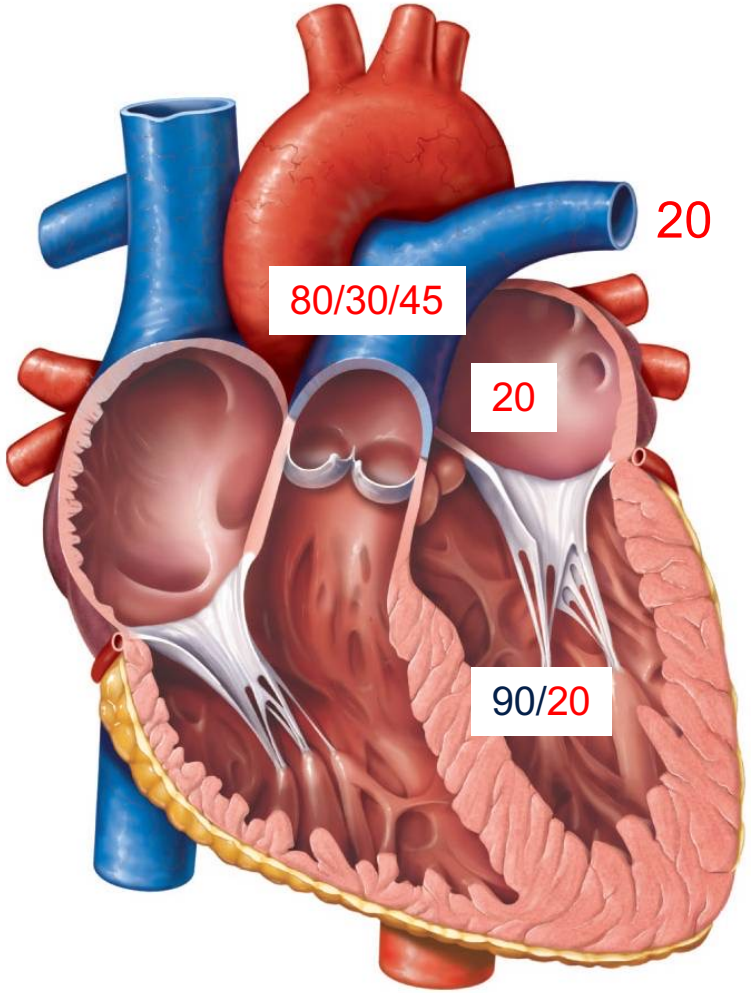
Kennedy, J. “Pulmonary Hypertension and Right Heart Failure”. Dec. 5, 2019.

(Post-Capillary) Pulmonary Hypertension



Kennedy, J. “Pulmonary Hypertension and Right Heart Failure”. Dec. 5, 2019.

(Pre & Post-Capillary) Pulmonary Hypertension



Kennedy, J. “Pulmonary Hypertension and Right Heart Failure”. Dec. 5, 2019.

Treatment

- Pulmonary vasodilator therapy mainly for group 1 and 4
  - PDE 5 inhibitor (sildenafil)
  - Endothelin receptor antagonist (Bosentan, Macitentan)
  - Prostacyclin (Epoprostenol) IV infusion pump at home
- Treatment of choice for group 4 is pulmonary endarterectomy
- Management of group 2 and 3 mainly focussed on the underlying heart or lung disease
- Transplantation (usually bilateral lung) remains the ultimate treatment option in PAH when other treatments fail.

Pulmonary Hypertension

- Goals of the pre-anesthetic consultation:
  - Targeted assessment of the severity of PH and/or right-sided HF.
  - **Functional status.**
  - Any modifiable factors that would optimize the patient's condition.
  - Optimization of diuretic treatment
  - Prehabilitation program
  - Perioperative anticoagulation
- Continue targeted PAH meds/optimization of treatment.
  - IV Epoprostenol in our patient. →

Risk assessment

Table 2 Variables used to predict mortality in pulmonary arterial hypertension and intensify treatment accordingly. This can be adapted to perioperative risk assessment to target preoperative PAH therapeutic optimisation to the 'low risk' column. RA, right atrial; RV, right ventricular; LV, left ventricular; F RV, ejection fraction; RVESVi, RV end-systolic volume index; LVEDVi, left ventricular end diastolic volume index; RVESvO_2, mixed venous oxygen saturations; CPET, cardiopulmonary exercise test; CI, cardiac index; RAP, right atrial pressure; 6MWD, 6 min walk distance; VO_2, oxygen uptake; BNP, brain natriuretic peptide; NT-proBNP, N-terminal BNP.

	Risk		
	Low	**Intermediate**	**High**
Clinical assessment			
Right heart failure	None	None	Present
Progression of symptoms	None	Slow	Rapid
Syncope	None	Occasional	Recurrent
Chest pain	None	Occasional	Recurrent
Arrhythmia	None	Occasional	Recurrent
WHO functional class	I/II	III	IV
Imaging and haemodynamics			
Echocardiographic	Preserved RV function. RA area <18 cm^2 No pericardial effusion	Impaired RV function. RA area 18–26 cm^2 No or minimal pericardial effusion	Impaired RV function. RA area >26 cm^2 Pericardial effusion present
Cardiac magnetic resonance	High RVEF (>54%) Normal RVESVi Normal LVEDVi	Reduced RVEF (37–54%) Increased RVESVi Decreased LVEDVi	Reduced RVEF (<37%) Increased RVESVi Decreased LVEDVi
Right heart catheterisation	RAP <8 mm Hg CI >2.5 L min^{-1} m^{-2} SvO_2 >65%	RAP 8–14 mm Hg CI 2.0–2.4 L min^{-1} m^{-2} SvO_2 60–65%	RAP >14 mm Hg CI <2.0 L min^{-1} m^{-2} SvO_2 <60%
Exercise capacity			
6MWD	> 440 m	165–440 m	< 165 m
CPET	Peak VO_2 >15 ml min^{-1} kg^{-1} (>65% predicted) VE/VCO_2 slope <36.0	Peak VO_2 11–15 ml min^{-1} kg^{-1} (35–65% predicted) VE/VCO_2 slope 36.0–44.9	Peak VO_2 <11 ml min^{-1} kg^{-1} (<35% predicted) VE/VCO_2 slope >45.0
Biomarkers			
BNP	< 50 ng L^{-1}	50–300 ng L^{-1}	>300 ng L^{-1}
NT-pro BNP	<300 ng L^{-1}	300–1400 ng L^{-1}	>1400 ng L^{-1}

Ratio of PSP/SBP less than 0.33 low risk vs more than 0.66 high risk

Risks associated with procedure

- Higher risk with
  - Emergency surgery
  - Length (more than 3h)
  - Type of surgery
- Non cardiac surgery considered high risk:
  - Thoracic surgery: high risk due to one lung ventilation and reduction of pulmonary vasculature in lung resection
  - General surgery : laparoscopic with pneumoperitoin causing hypercapnia and increased PVR and decreased venous return
  - Liver transplant: Patients with portopulmonary hypertension have 2x mortality risk
  - Obstetric: Major physiologic changes and fluid shifts. Severe PH considered CI to pregnancy
  - Orthopedic surgery: lower limb joint surgery with risk of intraprocedural pulmonary embolisation of bone marrow, cement, and bone debris causing an increase in PVR and acute RV failure
    - 4x adjusted risk of mortality (2.4% vs 0.6%) for patients with any type of PH undergoing total hip replacement

Counseling

- Patients with PH who require a surgical intervention or procedure should be counselled about the risk of perioperative complications including:
  - Death
  - Need for advanced cardiac support including ECMO
  - Ceilings of care
  - Outside an emergency setting, patients should be given sufficient time to formulate their decision

Pulmonary Hypertension & RV Failure

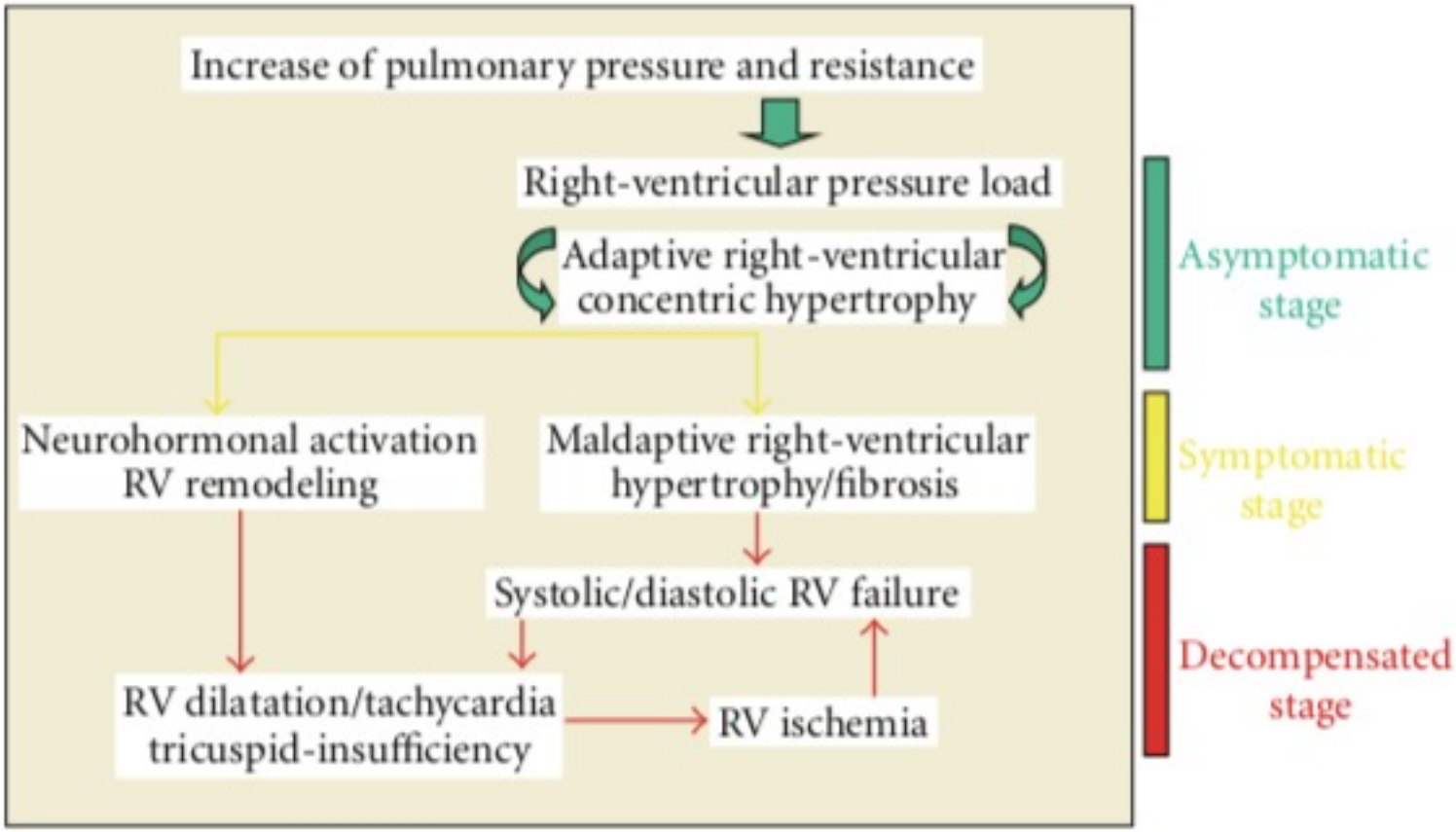


FIGURE 1: Development of right-ventricular failure in patients with pulmonary hypertension.

Kennedy, J. "Pulmonary Hypertension and Right Heart Failure". Dec. 5, 2019.

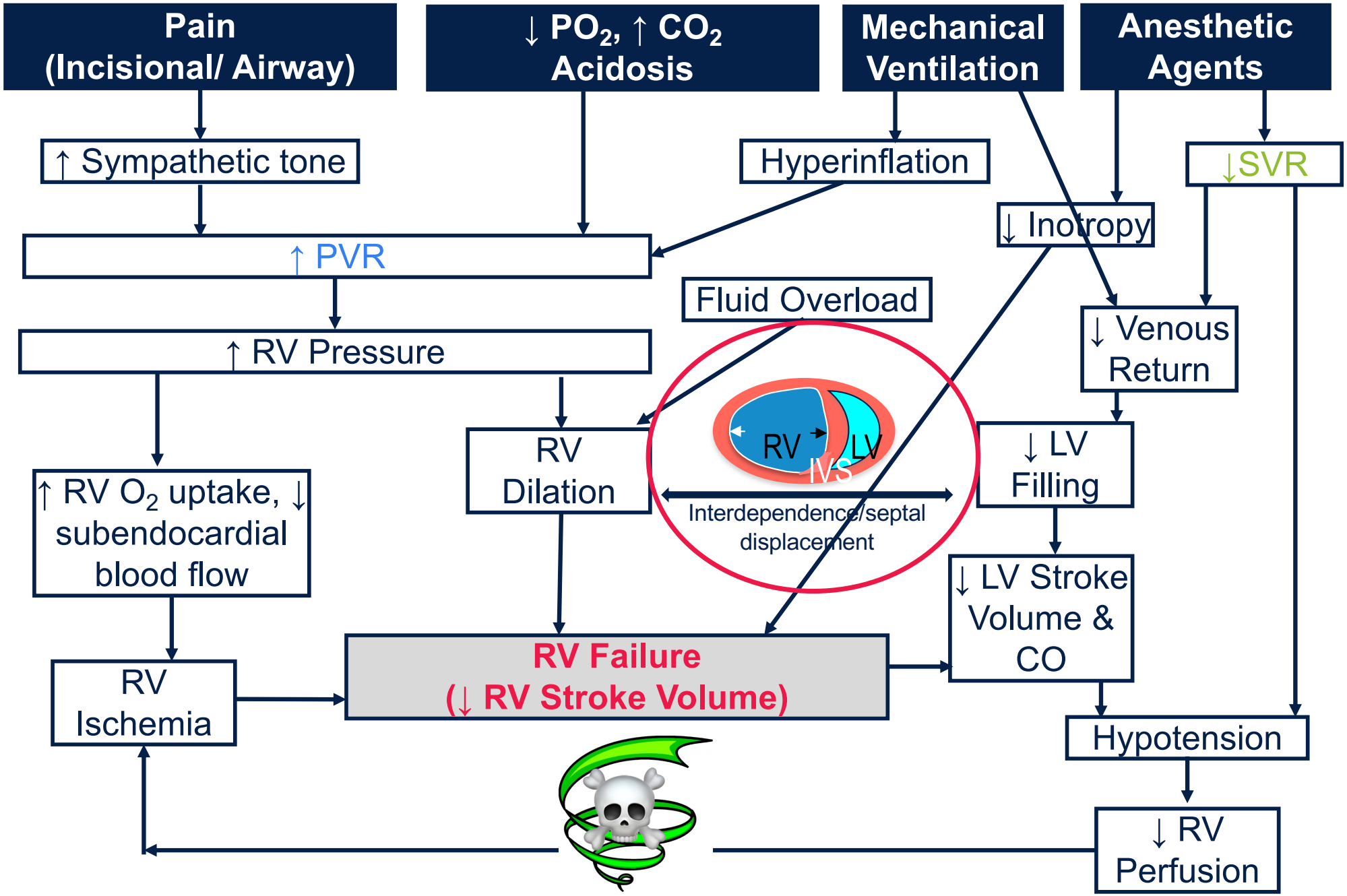
Pathophysiology of Intra-op RV Failure

Pain (Incisional/ Airway)

↓ PO_2, ↑ CO_2 Acidosis

Mechanical Ventilation

Anesthetic Agents


Pain (Incisional/ Airway)
↓ PO_2, ↑ CO_2 Acidosis
Mechanical Ventilation
Anesthetic Agents
↑ Sympathetic tone
Hyperinflation
↓SVR
↓ Inotropy
↑ PVR
Fluid Overload
↓ Venous Return
↑ RV Pressure
RV
LV
IVS
RV Dilation
↓ LV Filling
Interdependence/septal displacement
↑ RV O_2 uptake, ↓ subendocardial blood flow
↓ LV Stroke Volume & CO
RV Failure (↓ RV Stroke Volume)
RV Ischemia
Hypotension
↓ RV Perfusion

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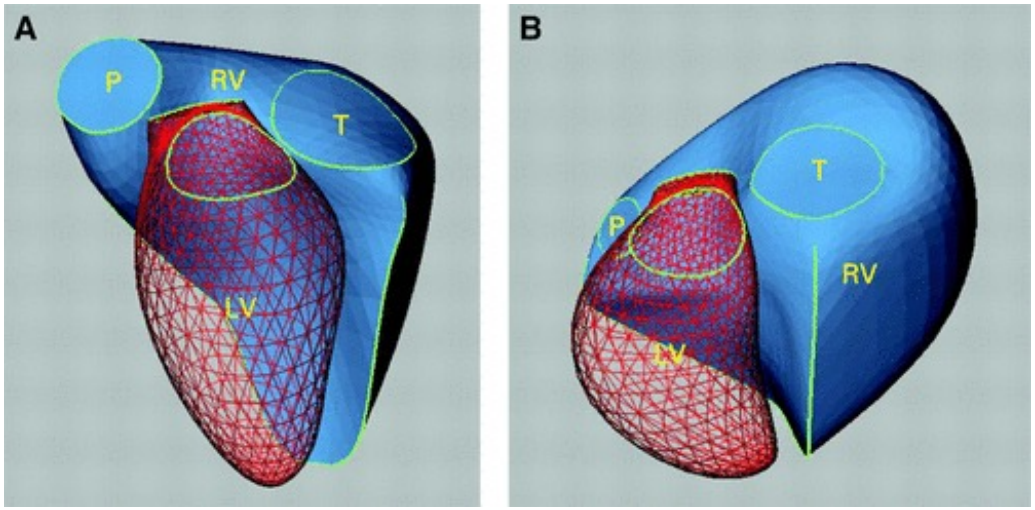
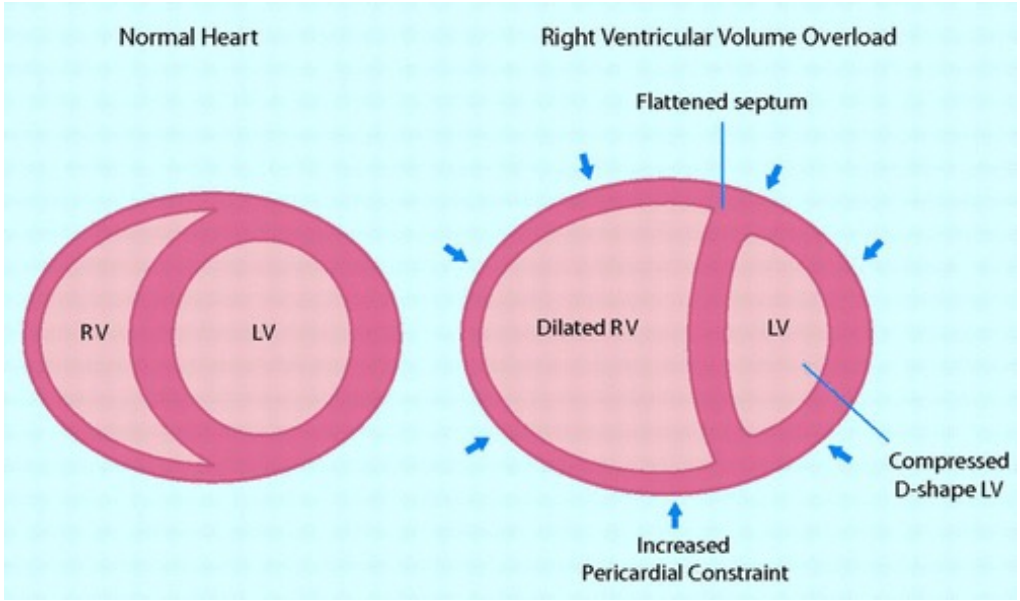
RV Geometry





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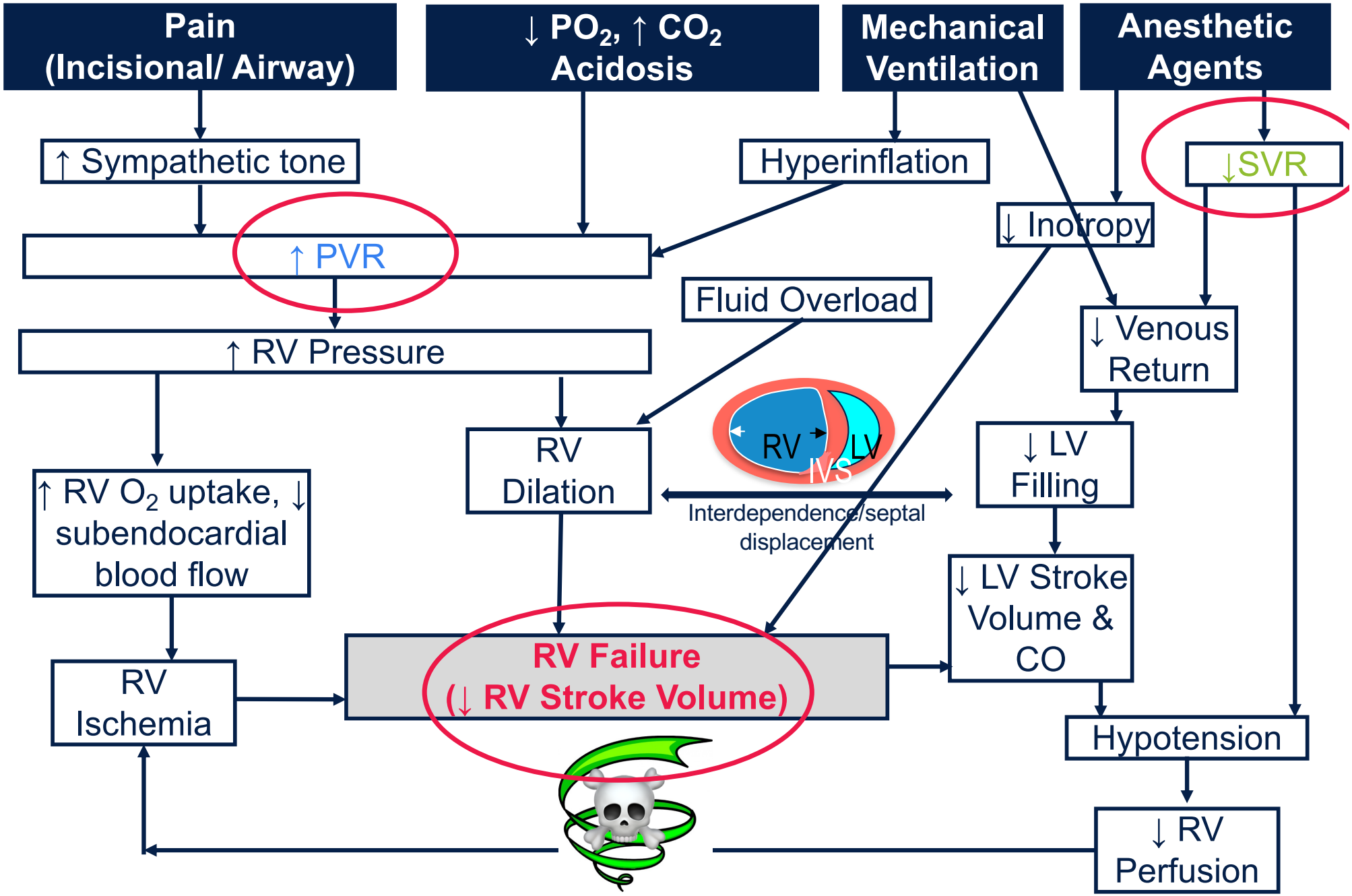
Pain (Incisional/ Airway)
↓ PO_2, ↑ CO_2 Acidosis
Mechanical Ventilation
Anesthetic Agents
↑ Sympathetic tone
Hyperinflation
↓SVR
↑ PVR
↓ Inotropy
Fluid Overload
↓ Venous Return
↑ RV Pressure
RV Dilation
RV
LV
IVS
Interdependence/septal displacement
↓ LV Filling
↑ RV O_2 uptake, ↓ subendocardial blood flow
↓ LV Stroke Volume & CO
RV Failure (↓ RV Stroke Volume)
RV Ischemia
Hypotension
↓ RV Perfusion

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Anesthetic Management

Goals

- Keep PVR down
- Maintain Contractility
- Maintain SVR

Avoid hypoxemia

Avoid hypercarbia

Avoid acidosis

Pulmonary vasodilators

Blunt pain response

Maintain normothermia

Spontaneous ventilation

Avoid lung overinflation

Inotropes

Sinus rhythm

Careful fluid administration

Vasopressors

Minimize agents that ↓ SVR

Anesthetic Management - Drugs

- **Vasopressors:**
  - Norepinephrine
  - **Vasopressin**
- **Inotropes:**
  - Dobutamine
  - Epinephrine
  - **Milrinone**
  - Calcium
- **Pulmonary Vasodilators:**
  - **Inhaled Nitric Oxide**
  - Inhaled Epoprostenol
- **If all fails:**
  - Mechanical circulatory support +/- lung transplant

Multidisciplinary team

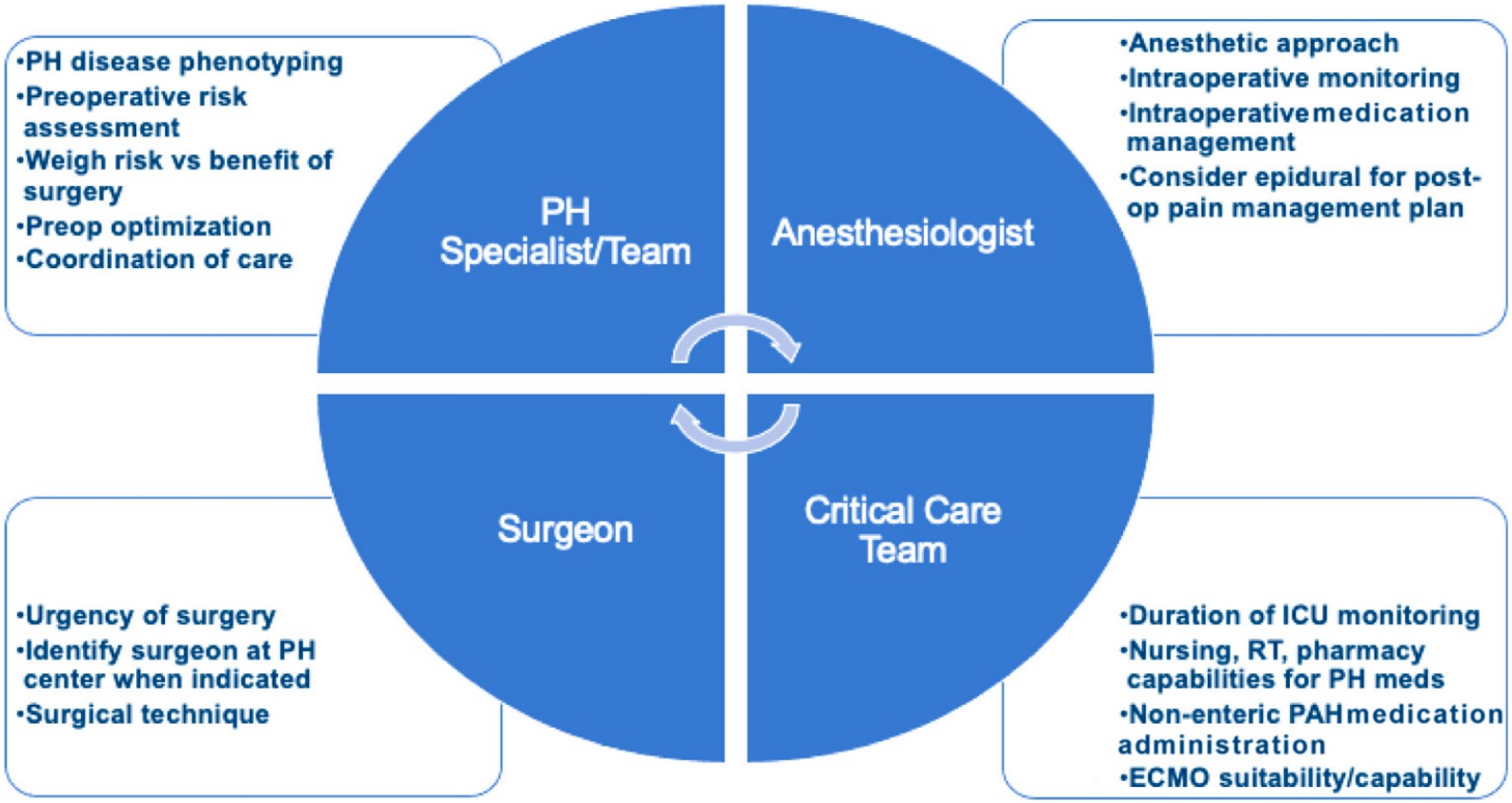


Figure 4 Preoperative multidisciplinary communications and planning: the core team.

Pre op checklist

- Who leads the team and who are the MDT members?

- Do we need to operate: risks *vs*. benefits *vs*. expected survival related to PH.
  - What information do we need to make this decision?
  - Are there non-surgical alternatives?

- Is this procedural sedation? Risk assessment is necessary
- Have we optimised the PH preoperatively?
- Do we need an updated RHC (and BNP, 6MW, echo, CPET) ?
- Risk assessment and consent for mortality. Family to be informed too
- Is patient suitable for ECMO, transplant, if needed

- Where to operate? PH centre; general or cardiac theatres
- Anaesthetic factors. GA *vs* regional? Do we need to modify the technique?
- Surgical approach: laparoscopy *vs* open surgery
- Perioperative monitoring including advanced cardiac output monitoring

- PAH therapies around GA/surgery/while fasted
- Anticoagulation around surgery (especially for CTEPH, arrhythmias, stroke)

- Preoperative checklist:
- PAH meds (IV epoprostenol, inhaled NO, iloprost)
- Plan for PH crisis (vasopressors, PH meds, inotropes, ECMO)
- Intraoperative monitoring (e.g. echocardiography)
- AICU/HDU bed booked for 48–72 h postoperative care

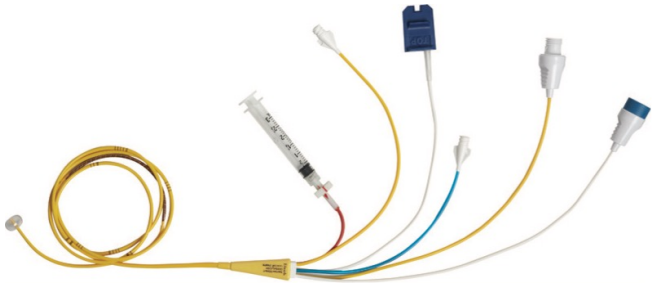
Anesthetic Management - Monitors

Intra-op Monitoring:

- Standard ASA monitors
- Arterial line (+pre-induction)
- Central line (+/- pre-induction)
- PA catheter (+/- pre-induction)
- TEE

9 Fr
10cm

PA Catheter



Information:

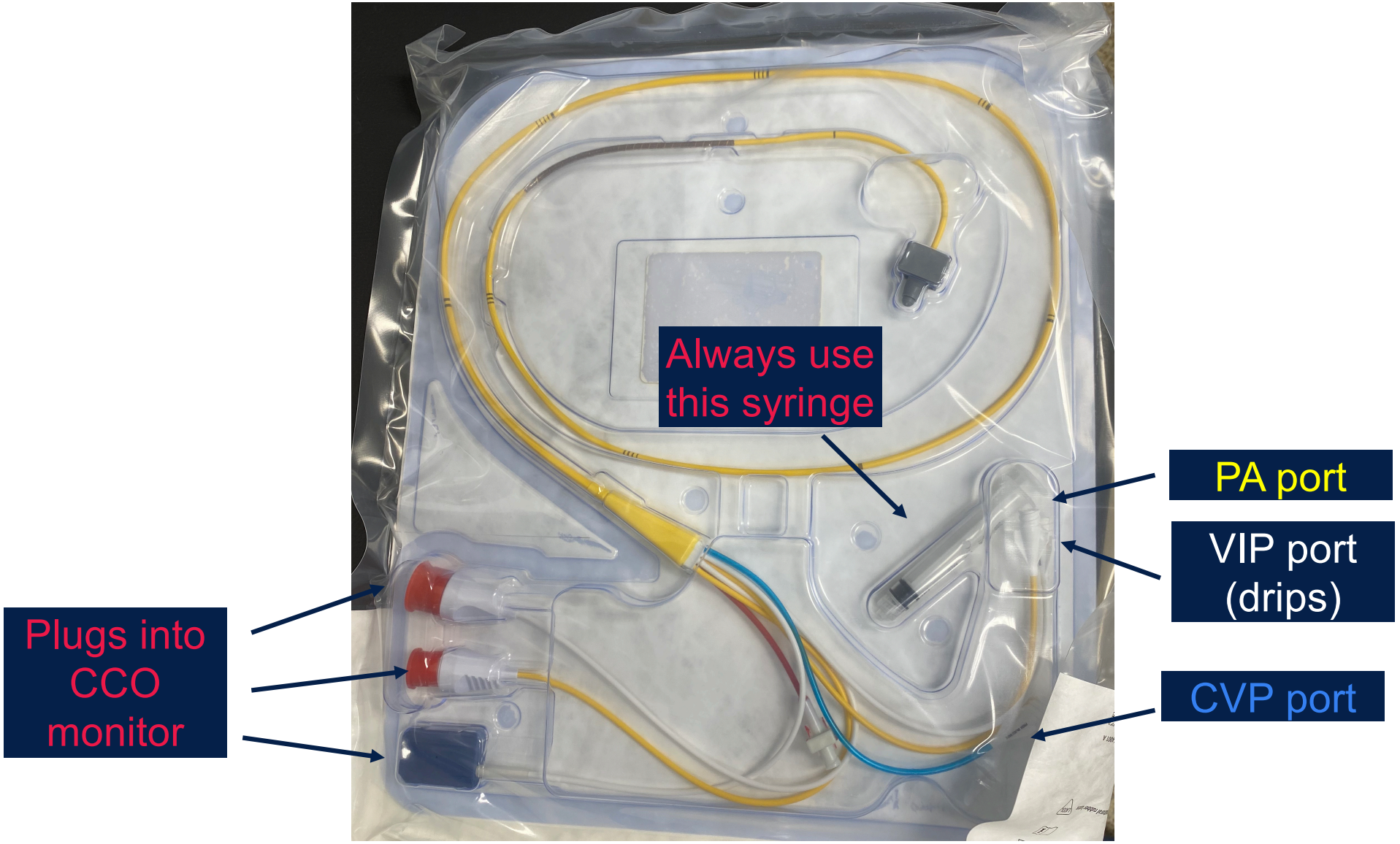
- **Trend pressures:** PAP, PCWP, right sided pressures: CVP/RA/RV.
- Measure cardiac output/index either continuously or via manual thermodilution.
- Measure mixed venous oxygen saturation.
- Calculate SVR, PVR

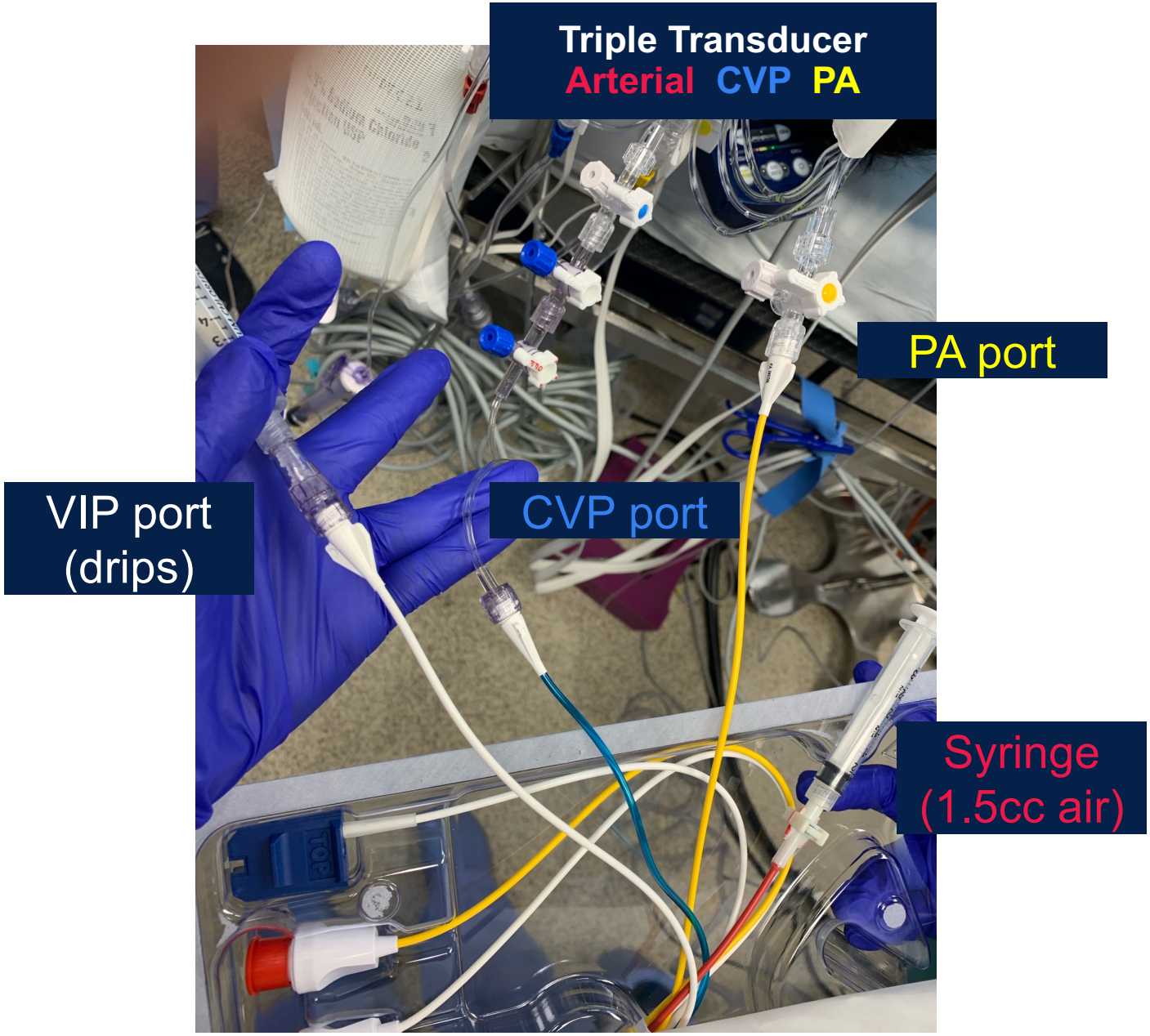
  - SVR = 80 x [MAP– CVP]/CO
  - PVR = 80 x [mPAP – PAOP]/CO

PA Catheter

- **Relative contraindications for Swan-Ganz pulmonary artery catheterization:**
  - Risk-benefit must be assessed for each patient.
- **Caution in:**
  - Left bundle branch block.
  - Patients with tricuspid or pulmonic heart valve replacements, stenosis.
  - Presence of endocardial pacing leads.

PA Line Insertion




Triple Transducer
Arterial CVP PA
PA port
VIP port
(drips)
CVP port
Syringe
(1.5cc air)

PA Line Insertion

The Steps:

- Connect ports to transducers.
- Flush ports.
- Check balloon.
- **Insert swan with balloon down (typically ~ 20cm), inflate balloon, float!**
- ALWAYS deflate balloon if pulling back.

PA Line Insertion

If advancing -> balloon up

If pulling back -> balloon down

Catheter insertion distance markings

Location	Distance to VC/RA Junction	Distance to PA
Internal jugular	15-20 cm	40-55 cm
Subclavian vein	10-15 cm	35-50 cm
Femoral vein	30 cm	60 cm
Right antecubital fossa	40 cm	75 cm
Left antecubital fossa	50 cm	80 cm

Note: Catheter markings occur every 10 cms and are denoted by a thin black line. 50 cm markings are denoted by a thick black line. Catheter must exit introducer sheath before inflating balloon.


Not Admitted
15 Dec 2020 13:25
Adult
PA Line Insert
ECG Check Cable
HR
80
PVC
12
ST-II -0.4
ST-V 0.0
ST-aVL 0.3
QTc 508
ΔQTc 49
QT 440
PAP
13/9
(11)
ART
105/60 (77)
CVP
(39)
PPV
-?-
Pulse
80
SpO2
100
Temp 36.5
NBP
-?-/-?- (-?-)
Alarm Limits
Main Setup
Main Screen
PHILIPS
Clinical Engineering
UCSF MEDICAL CENTER
146726
10
1006

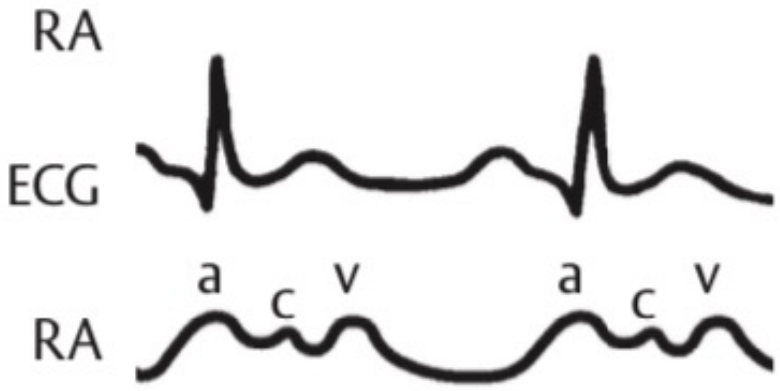
PA Line Insertion - Waveforms - CVP/RA

Right atrial/central venous pressure (RA/CVP)

2-6 mmHg

Mean 4 mmHg

- a = atrial systole
- c = backward bulging from tricuspid valve closure
- v = atrial filling, ventricular systole



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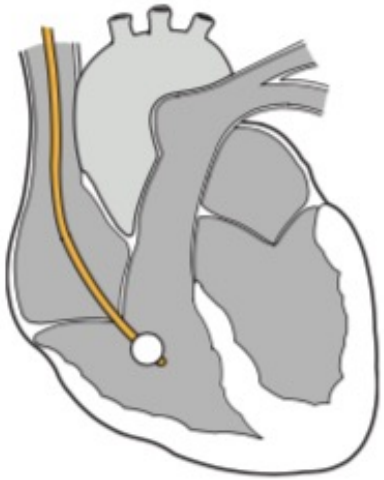
PA Line Insertion - Waveforms - RV

Right ventricle

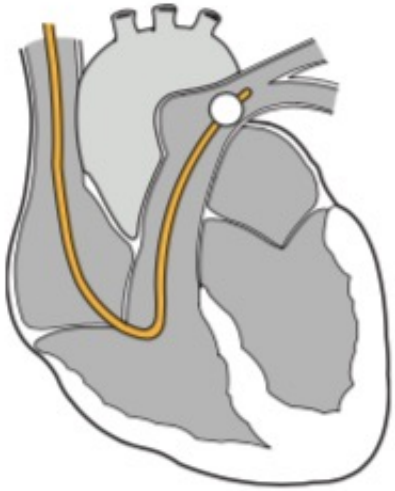
- Systolic pressure (RVSP)
  15-25 mmHg
- Diastolic pressure (RVDP)
  0-8 mmHg

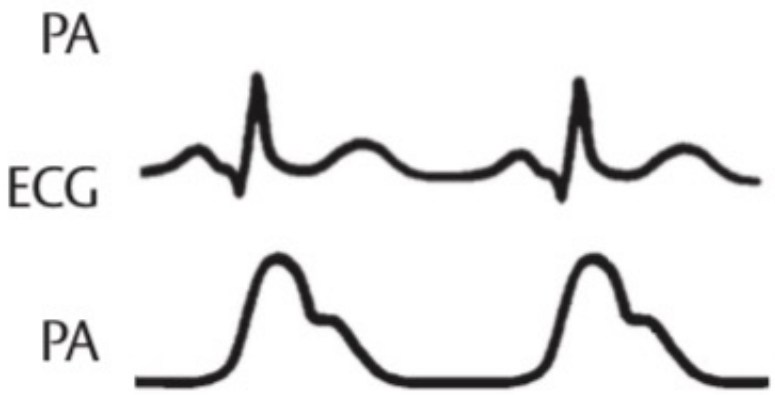


PA Line Insertion - Waveforms - PA

Pulmonary artery

- Systolic pressure (PASP) 15-25 mmHg
- Diastolic pressure (PADP) 8-15 mmHg
- Mean pressure (MPA) 10-20 mmHg



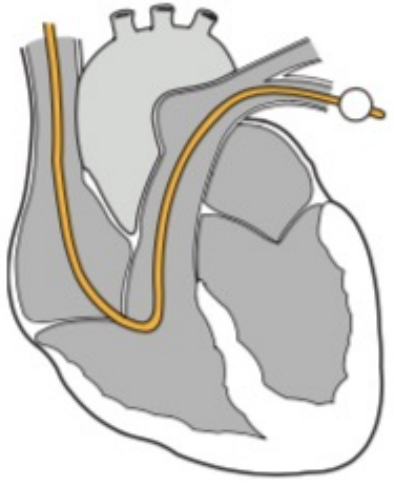


PA Line Insertion - Waveforms - PAOP

Pulmonary artery occlusion pressure (PAOP)

Mean 6-12 mmHg

- a = atrial systole
- v = atrial filling, ventricle systole



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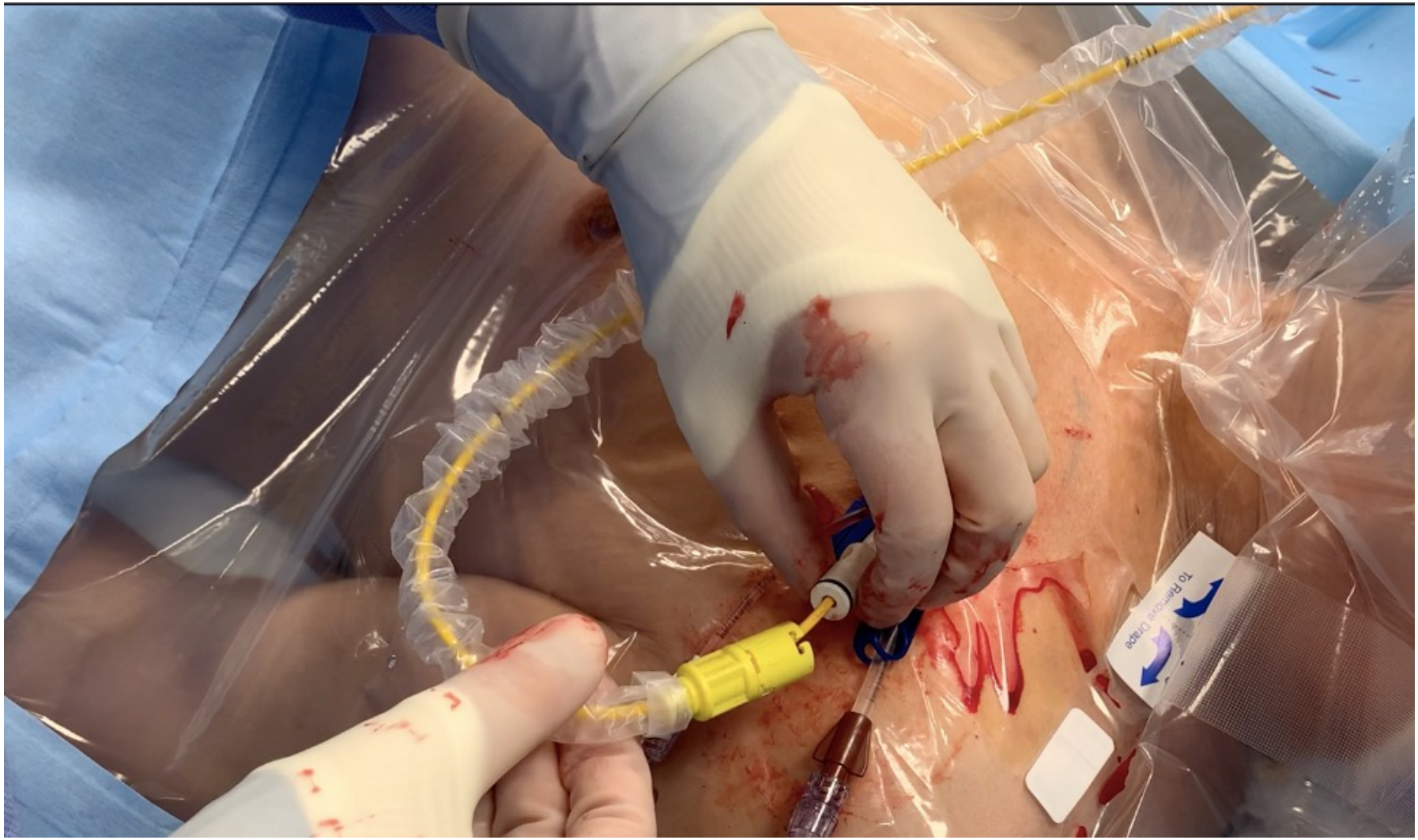
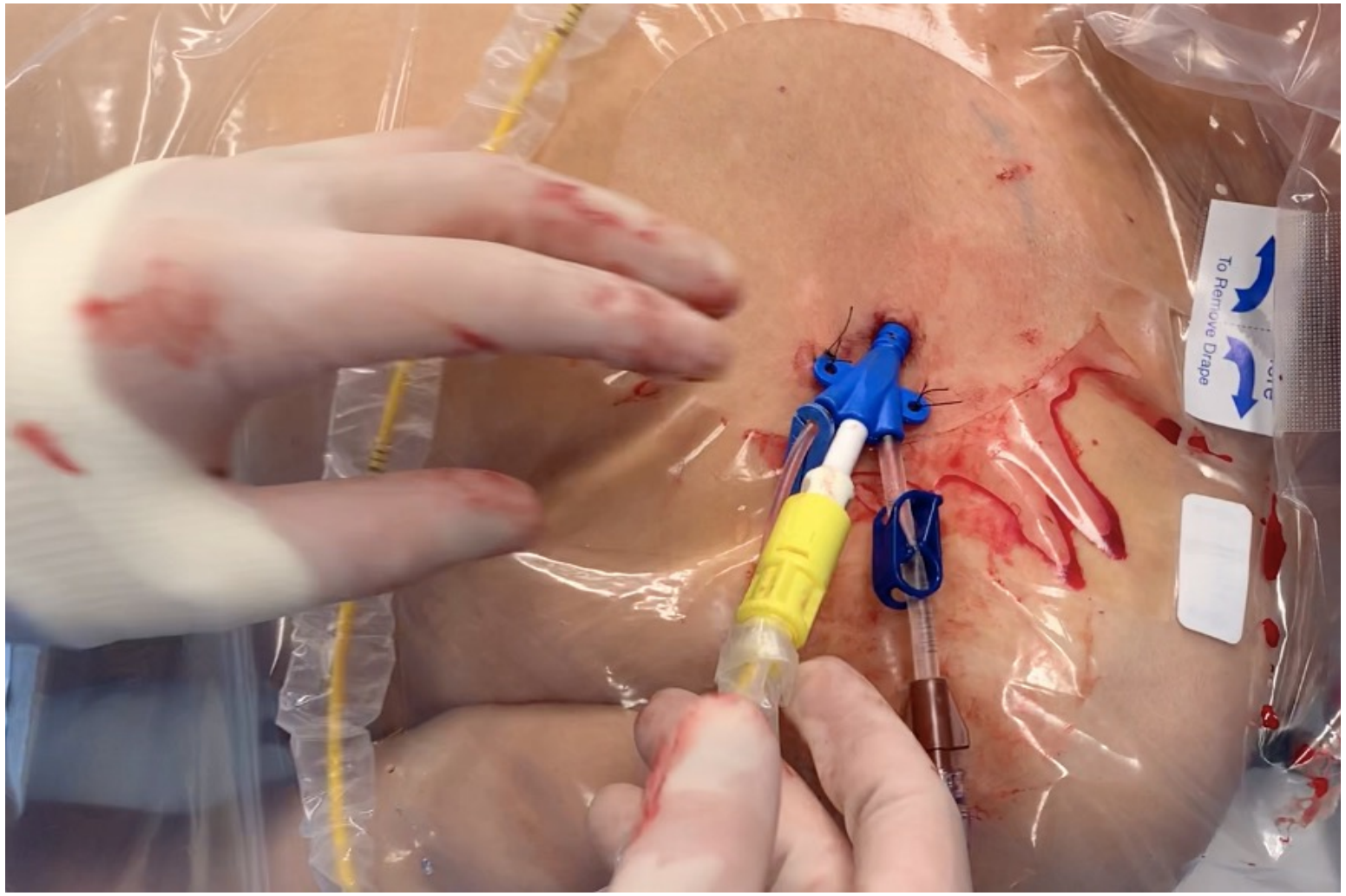
PA Line Insertion – Lock in place

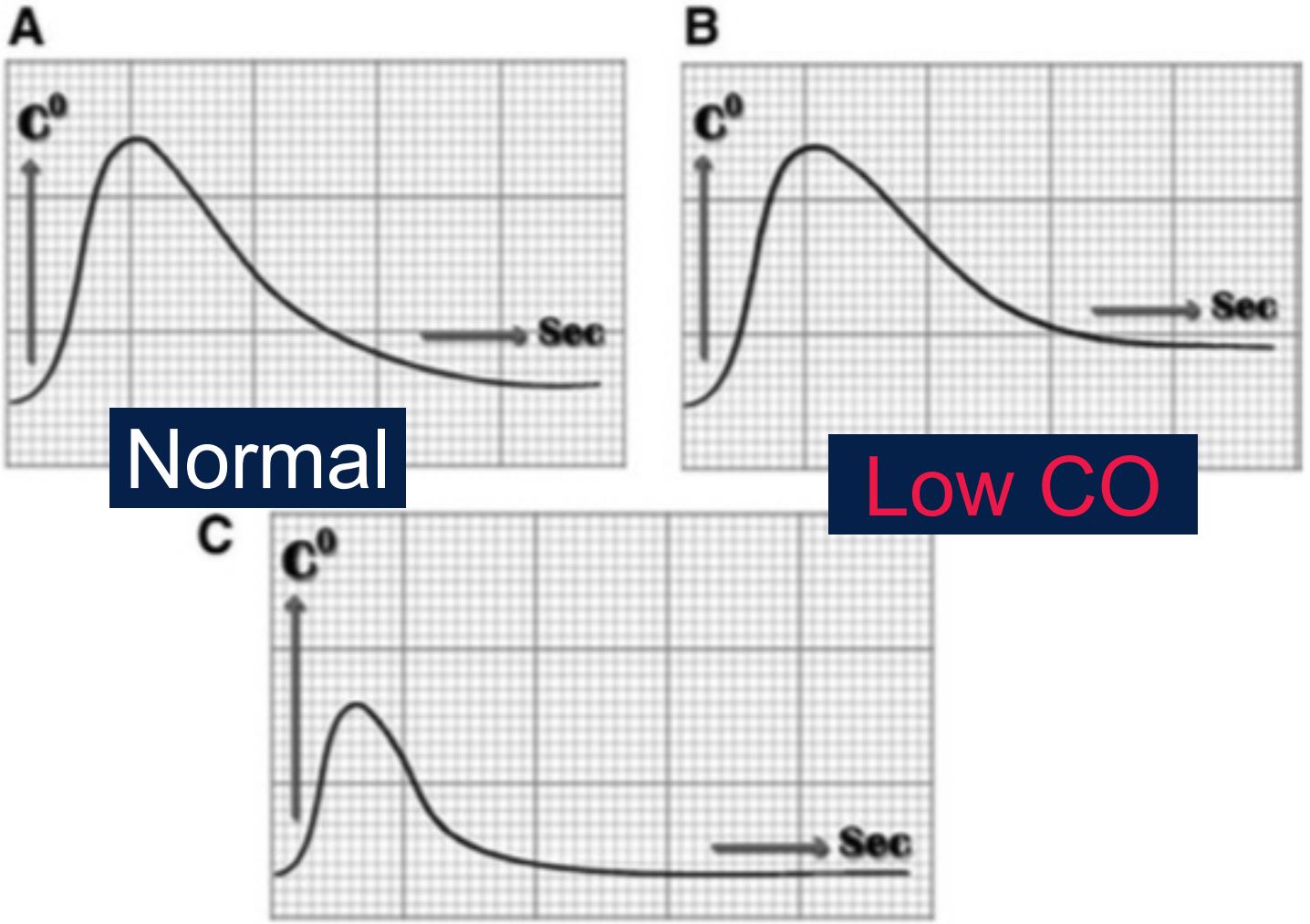
PA Line Insertion – Lock in place



PA Line Insertion – Lock in place



Cardiac Outputs – Thermodilution



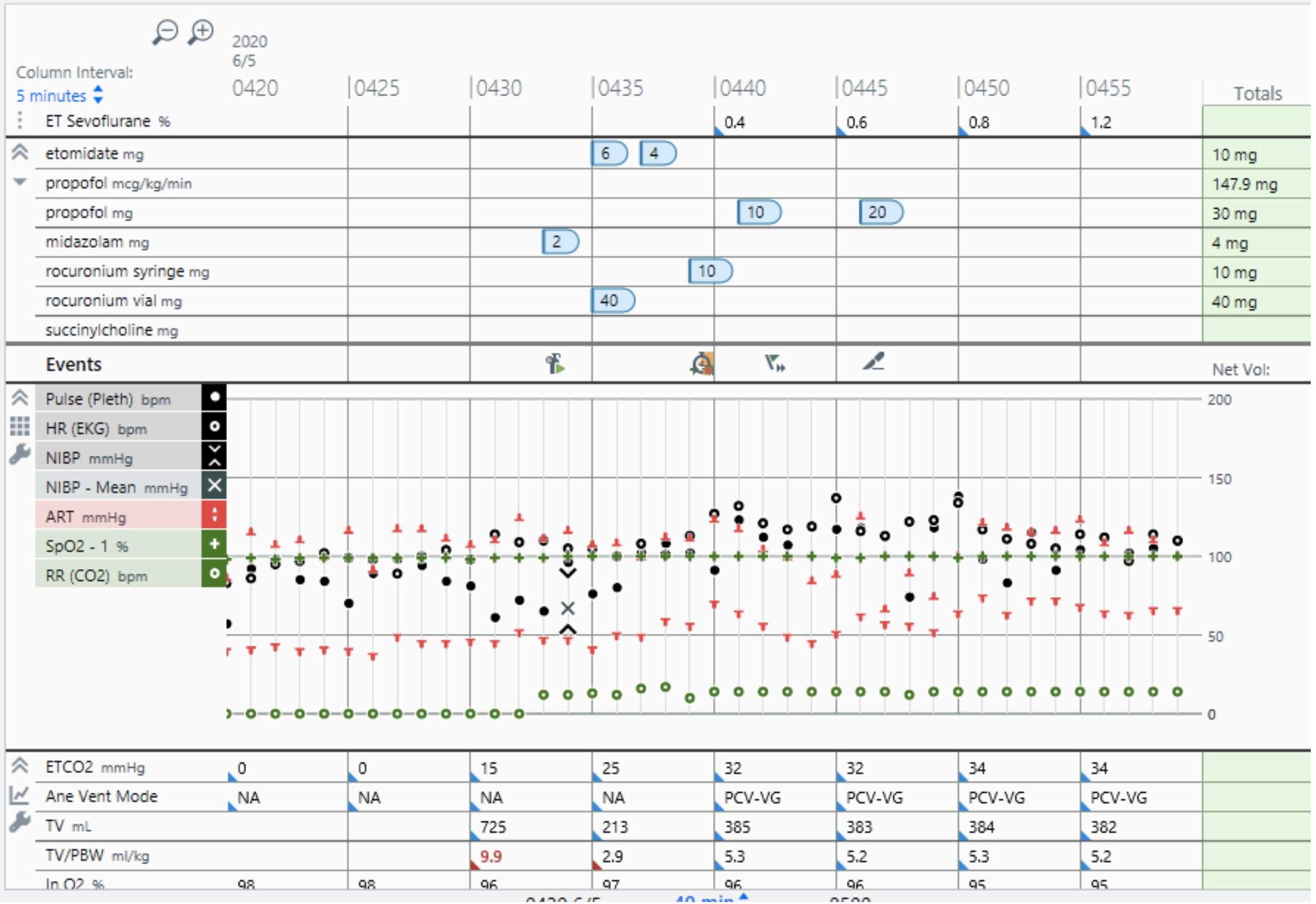
CCO Monitor


CCO MONITOR #2
OR 9
2.3
L/min/m²
CI
EDVI
mL/m²
4.6
L/min
CO
80
%
SvO2
08:34 am
09:04 am
09:34 am
10:04 am
10:34 am
10:21:51 am
12/15/20
Swan-Ganz
BT: 36.2°C
Alert: EDV – Heart Rate Signal Loss

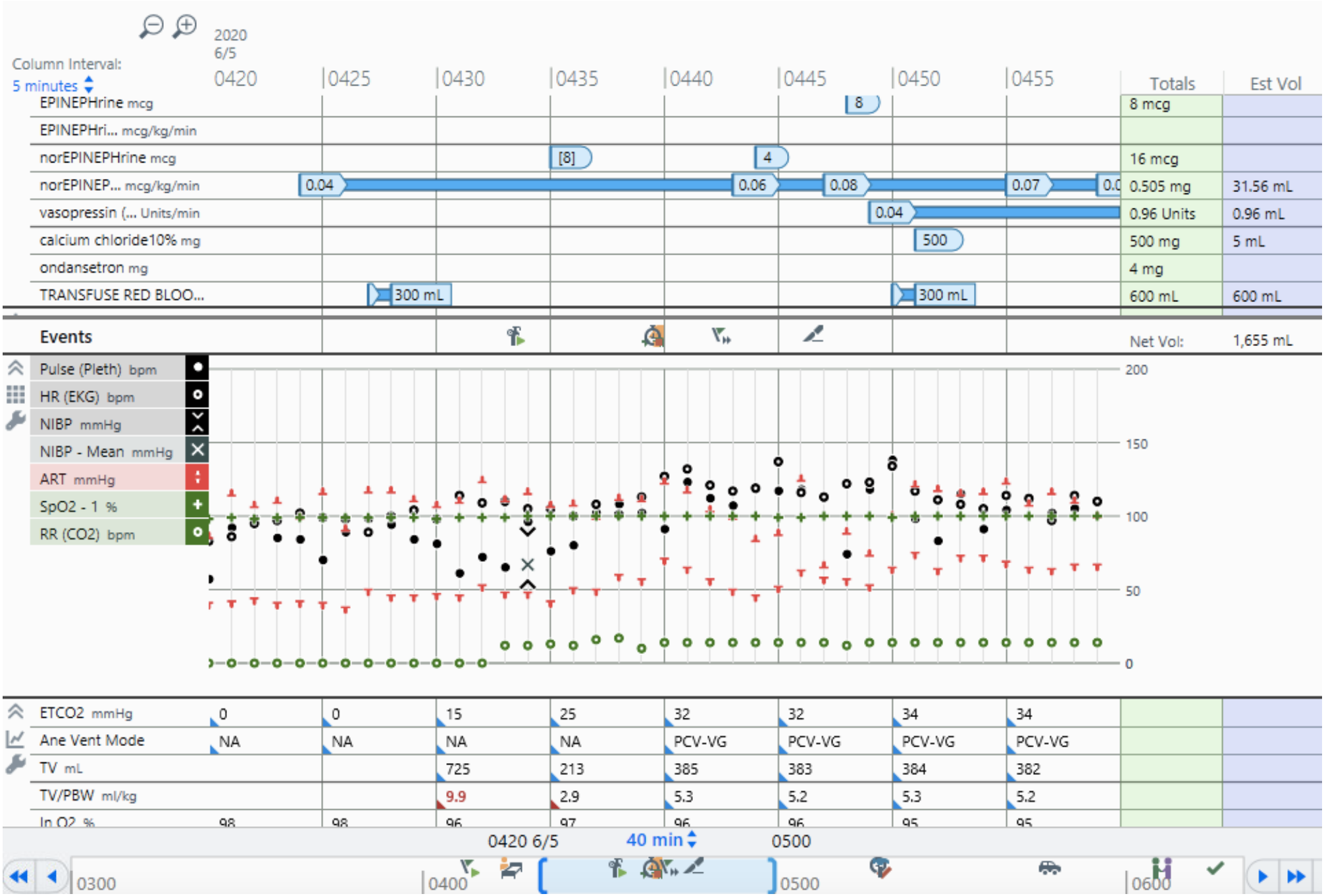
Post op care

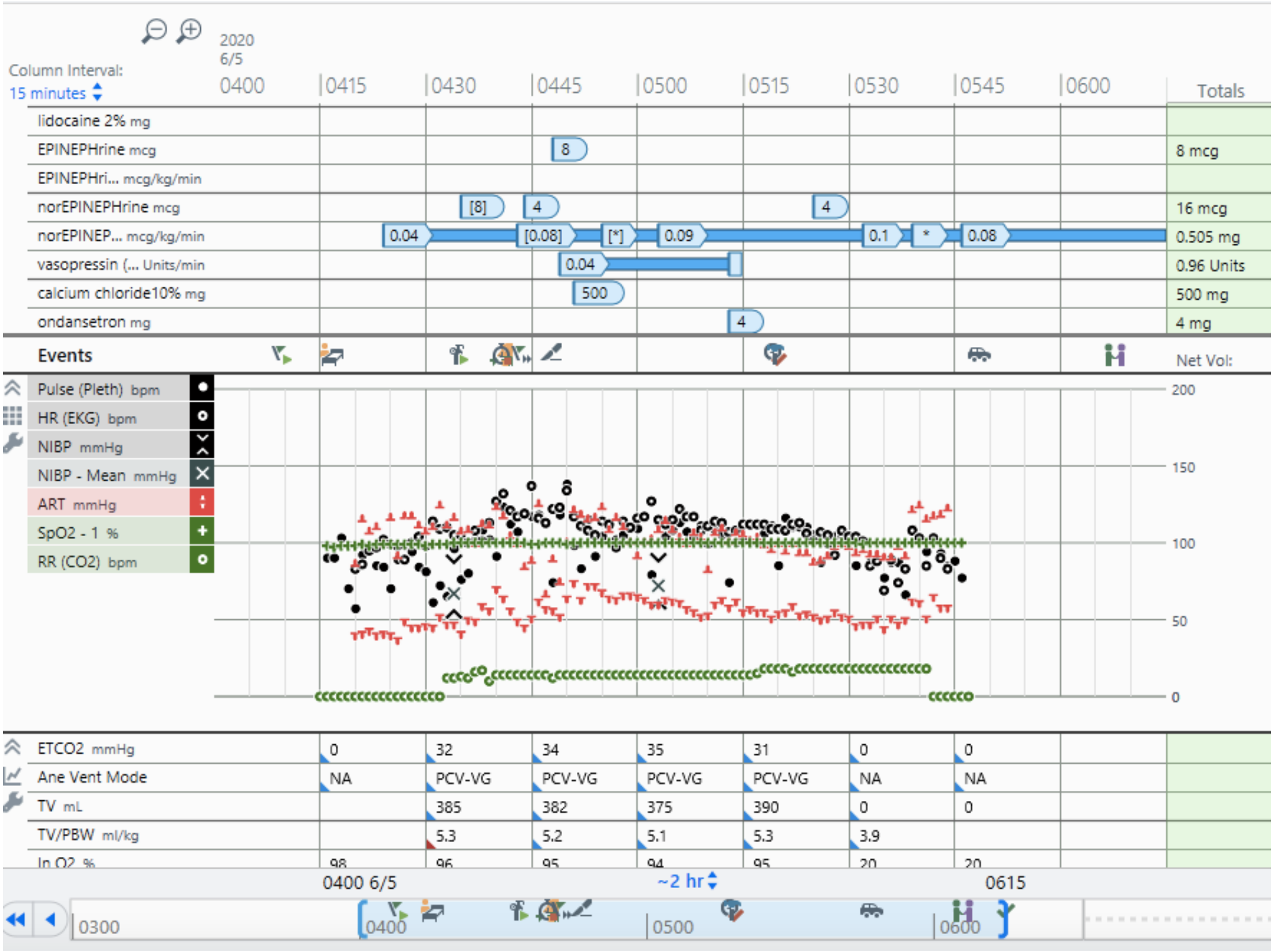
- Most perioperative morbidity and mortality events related to RV dysfunction and can occur up to 48-72 h after seemingly uncomplicated surgery
- ICU or high dependency unit (HDU)
- Pre op PAH therapies should not be interrupted, and if introduced intra op it should be slowly weaned
- If previously anticoagulated, should be resumed as soon as surgically safe
- Analgesic control matters
- Achieving spontaneous ventilation ASAP and early extubation
- Postoperative physiotherapy, prophylaxis for deep venous thrombosis and early mobilisation also indicated

Back to the clinical case



Back to the clinical case




2020
6/5
Column Interval:
15 minutes
0400
0415
0430
0445
0500
0515
0530
0545
0600
Totals
lidocaine 2% mg
EPINEPHrine mcg
8
8 mcg
EPINEPHri... mcg/kg/min
norEPINEPHrine mcg
[8]
4
4
16 mcg
norEPINEP... mcg/kg/min
0.04
[0.08]
[*]
0.09
0.1
*
0.08
0.505 mg
vasopressin (... Units/min
0.04
0.96 Units
calcium chloride10% mg
500
500 mg
ondansetron mg
4
4 mg
Events
Net Vol:
Pulse (Pleth) bpm
HR (EKG) bpm
NIBP mmHg
NIBP - Mean mmHg
ART mmHg
SpO2 - 1 %
RR (CO2) bpm
200
150
100
50
0
ETCO2 mmHg
0
32
34
35
31
0
0
Ane Vent Mode
NA
PCV-VG
PCV-VG
PCV-VG
PCV-VG
NA
NA
TV mL
385
382
375
390
0
0
TV/PBW ml/kg
5.3
5.2
5.1
5.3
3.9
In O2 %
98
96
95
94
95
20
20
0400 6/5
~2 hr
0615
0300
0400
0500
0600

Conclusion

- Pulmonary hypertension is a complex topic
- Safe anesthetic management of these patients = keeping in mind the hemodynamic goals and knowing treatment options
- Do not hesitate to ask for help when needed

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