Low SpO_2

Is BP Low?

No

Yes

or

Yes

Low SpO_2

LOW SpO_2

- Confirm oxygen lines/flowmeters connected, SWEEP speed ≥ 1L/min and FDO_2 at expected setting
- Increase FDO_2 to 1.0 while troubleshooting; monitor SpO_2 response; page RRT in case increased ventilation required
- Rule-out changes in blood flow rate, drainage SvO_2, ECMO pressures, access/return color difference, chatter
- Any recent changes to ECMO or ventilator? Or was patient recently repositioned? Return to previous settings/position
- If drainage insufficiency unlikely (no chatter/P_{ven} not extremely negative), increase RPMs by increments of 100 revolutions per minute. Monitor for appropriate increase in blood flow and SpO_2 without significant pressure changes.
- RRT to reassess lung compliance and/or increase mechanical ventilation for persistent/unresolved hypoxemia
- Page perfusion and notify CCTC Consultant/Senior (STAT if hypoxemia persists)
- Repeat arterial blood gases
- Rule out Patient and/or Circuit Causes for Hypoxemia (see reverse)

CARDIAC ARREST?

- Initiate CPR and activate bedside emergency call button
- If not oxygenating – Announce "OFF ECMO" and initiate full mechanical ventilation
- Maintain FDO_2 1.0 and increase blood flow rate if tolerated; continue mechanical ventilation if SpO_2/$ETCO_2$ inadequate
- Page perfusionist STAT

HYPOTENSION?

- FDO_2 1.0
- Assess lines and tubes
- Initiate/increase vasopressors
- Consider fluid bolus, especially if P_{ven} more negative
- Assess Hb on ECMO circuit; rule-out bleeding and confirm with CBC
- Notify CCTC Consultant/Senior and perfusionist (Post the on-call Perfusion Pager each Shift)
- Rule out Patient and Circuit Causes (see reverse)

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Hypotension

Rule-out

PATIENT CAUSES

- Hypovolemia (may have signs of drainage insufficiency)
- Bleeding (site, assess Hb on drainage sensor)
- Pneumothorax (decreased VT/VE, decreased lung compliance, SQ air)
- Cardiac tamponade/pericardial effusion
- Intraabdominal Hypertension
- Cardiac event (e.g. ischemia/MI)
- Pulmonary Embolus
- Sepsis

CIRCUIT CAUSES

- Drainage insufficiency (P_{ven} very negative/fluctuating, fluctuating blood flow, chatter)
- Return obstruction (increased P_{ven} and P_{art}, unchanged Δ P, decreased/absent blood flow)
- Bleeding from circuit disruption
- Accidental decannulation

Hypoxemia

Rule-out

PATIENT CAUSES

- Worsening compliance in a patient who is oxygenating/dependent on some native lung function
- Pneumothorax
- Pulmonary Embolism
- Intolerance to ECMO weaning

CIRCUIT CAUSES

- Incorrect oxygen setup (disconnected oxygen tubing, flow meter off/damaged, sweep speed < 1L/min minimum)
- Drainage insufficiency (P_{ven} very negative/ fluctuating, fluctuating blood flow, chatter)
- Return obstruction (Increased P_{ven} and P_{art} , ΔP unchanged, blood flow decreased or absent)
- Recirculation (drainage SvO_2 high and SpO_2 low, lack of colour differentiation between access and return)
- Blood flow too low
- High patient cardiac output (blood flow goal is 50-60% of cardiac output)
- Cannula displacement

DRAINAGE INSUFFICIENCY

DIAGNOSE

- Increased access negativity (P_{ven} becomes more negative)
- Chatter
- Fluctuating P_{ven} and Blood Flow (blood flow drops due to inability to pull enough blood)

Yes

CIRCUIT CAUSES:

- Blood flow too high
- Drainage cannula too small
- Kink, clot or obstruction in drainage catheter

PATIENT CAUSES:

- Patient coughing, Valsalva, agitation
- Pneumothorax (decreased TV/VE, decreased compliance)
- Dynamic Hyperinflation (increased PIP/Expiratory Pressure, autoPEEP (PEEP < expiratory pressure))
- Cardiac tamponade
- Increased Intraabdominal pressure

Interventions

CORRECTION

- Temporarily decrease RPMs by increments of 100 revolutions until chatter stops, P_{ven} returns to baseline and blood flow stops fluctuating
- Minimum blood flow 2.5 L/min (to prevent clotting)
- R/O and correct kinks or obstructions between patient and machine, or patient agitation, coughing
- If induced by patient repositioning, return to previous position
- RN may trial 200 ml bolus 0.9% NaCl; reassess P_{ven}, blood flow and SpO_2 response
- Consider POCUS
- Obtain Chest Xray
- Page perfusionist and CCTC Consultant/Senior

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RETURN OBSTRUCTION

DIAGNOSE

- Increased P_{ven} and P_{art}
- Unchanged ΔP
- Blood flow decreased or absent

+/- Sudden hypoxemia and/or Hypotension

Interventions

CORRECT

Assess and relieve any return obstruction

- Membrane lung dysfunction, clot or obstruction
- Return tubing
- Return cannula
- Return vessel
- Assess patient position/recent repositioning

CIRCUIT CAUSES

Extra Luminal

- Clamp, kink or compression of tubing between blood pump and patient return cannula
- Return cannula displacement (if happens with repositioning, immediately return to previous position)
- Clot in vessel impeding return flow

Intraluminal

- Thrombosis (maintain adequate anticoagulation)

PATIENT CAUSES

VVE Causes

- Factors that increase RA pressure (tension pneumothorax, intraabdominal hypertension, tamponade)
- Coughing, Valsalva

VAE Causes

- Hypertension
- Aortic dissection

Urgent

EMERGENCY INTERVENTION

If unable to resolve Immediately:

- Return to full ventilation
- Initiate CPR/ACLS for cardiac arrest
- Treat hypotension if required
- Consider POCUS
- **Page Perfusion and Consultant STAT**

RECIRCULATION

DIAGNOSIS

Hypoxemia *with*

- No difference in access and return blood colour
- SvO_2 (from drainage sensor) higher (like arterial gases) than patient SpO_2

Some recirculation is inevitable; clinical perfusionists will assess pre and post membrane gases to calculate daily to monitor severity

CIRCUIT CAUSES

- Blood flow too high
- Cather drainage and return ports too close together

PATIENT CAUSES

- Decrease in native cardiac output without a change in circuit blood flow

Interventions

CORRECT

- Decrease RPMs in increments of 100 RPMs to lower blood flow rate (assess response to blood flow, drainage catheter SvO_2, SpO_2 and catheter color difference). Minimum blood flow 2.5 L/min
- Return patient to previous bed position if change occurred with repositioning
- Obtain Chest Xray
- Page Perfusionist and CCTC Consultant (catheter repositioning or change may be required)

Air Entrainment

DIAGNOSIS

Disruption/opening of circuit pre blood pump allows air to enter membrane side

- **Large air volume can deprime the pump**
- Identified by whirring sound of blood flow
- Small amounts of air should become trapped and can be vented out by perfusionist
- Small volumes of air can be released post membrane and activate the return catheter bubble sensor

CIRCUIT AND VASCULAR ACCESS CAUSES

- Air in circuit during initial priming and connection
- Circuit breach/lack of luer-lock caps on pre blood pump side
- Air entry from intravenous catheters (e.g. bubbles introduced during medication bolus, failure to clamp CVC when changing needleless access device)
- Partial or complete decannulation of drainage catheter

Urgent

Bubble Sensor Activated (visual and auditory alarm)

Assess post membrane circuit

- If air is visualized, clamp return line followed by drainage catheter (or clamp simultaneously)
  - Activate bedside emergency call button for Physician/RRT and identify "OFF ECMO"
  - Initiate full mechanical ventilation on 100% oxygen
  - Page perfusionist STAT
- If no visible air, continue to monitor closely for changes in BP or SpO_2
- Reassess all IV tubing sets (peripheral and central) for potential air

Intervention

AIR EMBOLISM INTERVENTION

- If air has entered return cannula; clamp return line followed by drainage catheter (or clamp simultaneously) and initiate full mechanical ventilation
- **VVE** - position patient head down (Trendelenburg) on left side (to trap air in RV). Attempt to aspirate air from drainage catheter and/or CVC if possible.
- **VAE** – do not position head down on left; air entry to arterial circuit may travel to brain (ischemic stroke) or other organs and cause end organ infarction.

Attention needed

AIR VISIBLE IN MEMBRANE WITHOUT BUBBLE SENSOR ACTIVATION

- Observe filter and notify perfusionist (air can be vented by clinical perfusionist)

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PARTIAL OR COMPLETE DECANNULATION

DIAGNOSIS

A PRE BLOOD PUMP circuit breach causes air to enter the ECMO circuit (negative pressure side). This includes partial or complete drainage catheter decannulation.

A circuit breach POST BLOOD PUMP causes bleeding while the pump is running (positive pressure).

Complete decannulation of either the drainage cannula or a venous return cannula (VVE) will cause bleeding. However, the large tract can also provide an avenue for venous air embolism from either VV ECMO cannula until adequate hemostasis is achieved.

Decannulation of the return catheter in a VA ECMO circuit will cause bleeding.

Intervention

Decannulation Emergency

- For partial or complete decannulation immediately clamp the return catheter, followed by drainage catheter and apply direct pressure to site of decannulation.
- Activate bedside emergency call button for Physician/RRT and identify “OFF ECMO”
- Initiate full mechanical ventilation on 100% oxygen
- Page Perfusionist STAT

AIR EMBOLISM INTERVENTION

- If air has entered return cannula; clamp return line followed by drainage catheter (or clamp simultaneously) and initiate full mechanical ventilation
- **VVE** - position patient head down (Trendelenburg) on left side (to trap air in RV). Attempt to aspirate air from drainage catheter and/or CVC if possible.
- **VAE** – do not position head down on left; air entry to arterial circuit may travel to brain (ischemic stroke) or other organs and cause end organ infarction.

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Blood Gas Correction with ECMO Membrane

HOW TO FIX LOW PaO_2/SpO_2 WITH ECMO

Increase FDO if not at 1.0

Ensure Sweep speed is set to at least 1 L/min.

Increase RPMs in increments of 100 (rpms) to raise blood flow.

Blood flow should be 50-60% of native cardiac output.

Rule-out other patient and circuit causes for hypoxemia.

HOW TO FIX HIGH $PaCO_2$ WITH ECMO

Increase Sweep Speed (see calculation below)

Avoid rapid reduction/correction of $PaCO_2$; rapid reduction can cause cerebral vasoconstriction with impaired cerebral perfusion. Gradual target reduction should be achieved.

CALCULATION TO GUIDE SWEEP SPEED CHANGES

SWEEP SPEED RATE SETTING =

$$\frac{\text{Current Sweep Speed (L/min)} \times \text{Current } PaCO_2}{\text{TARGET } PaCO_2}$$

Cardiac Arrest While on ECMO

VVE

Cardiac Arrest
Pulseless
VT/VF/PEA/Asystole

Initiate CPR and ACLS
Activate Emergency Buzzer

Adequate SpO_2?

- No → Continue VVE and Ventilatory as previous
- Yes → "OFF ECMO" Maximize Ventilator Settings

VAE

Cardiac Arrest
VT/VF/PEA/Asystole

Adequate SpO_2 and BP?

- No
  - Activate Emergency Buzzer
  - Immediate CPR not needed
  - MD to determine need for defibrillation and CPR
- Yes
  - Initiate CPR and ACLS
  - "OFF ECMO"
  - Maximize Ventilator Settings

Important Principles

- When potential initiation of ECMO is being discussed, all line insertion should be done by an experienced Senior Resident or Consultant, in consultation with the physician who will cannulate (for preservation of vascular access and assignment of catheter placement)
- Ensure $ETCO_2$ is connected prior to cannulation (and compared to $PaCO_2$; to monitor for potential rapid reduction in CO_2)
- All ECMO and mechanical ventilation orders must be provided by CCTC Consultant/Senior Resident
- Perfusion must be present for transport of patient, bubble study, procedures requiring injection, or central line insertions (plan in advance for elective interventions)
- Only CCTC Consultant or Senior Resident to place CVCs or Arterial Lines
- Trend SpO_2 and $ETCO_2$ for oxygenation and carbon dioxide monitoring; confirm by blood gas and adjust to achieve target SaO_2/PaO_2 and $PaCO_2$
- Be very careful/add air venting filters when giving medication (micro air bubbles will be pulled into membrane and may enter return side)