I. Inadequate Gas Exchange

Objective- identify a gas exchange problem during CPB and investigate gas supply or blood path problem in the circuit. Demonstrate oxygenator change out.

Scenario- five minutes after the onset of CPB. The CPB circuit arterial line is noticeably dark and the mixed venous oxygen saturation probe is reading 30%.

What is the rate of Oxygenator Failure?

Survey Data-

1980 Stoney Failure rate 1: 46,852 (surveyed surgeons)
1986 Kurusz Failure rate 1: 13,662 (surveyed perfusionists)
1996 Fisher Failure rate 1: 4,000 (UK)
1999 Mejak Failure rate 1: 2,458
2006 Charrière Failure rate 1: 7,201 (France)
2006 Charrière Increased resistance to flow 1: 422 (France)

Why do Oxygenators Fail?
1. Manufacturer Defect
2. Patient Factors - Hyper-coagulation states, Thrombocytosis, Platelet abnormalities
3. Operator error- gas supply interruption, perfusion technique inadequate anticoagulation

What should programs do to prepare for oxygenator failure?

a. Programs should have:
   i. A change-out protocol.
   ii. Alternate gas supply readily available
   iii. Change out supplies available in the OR.

b. Teams should do periodic oxygenator failure simulation drills.
   i. Include early identification of failure
   ii. Communication
   iii. Decision making
   iv. Practice drills

Parallel Replacement of an Oxygenator Not Transferring Oxygen (PRONTO)
A rapid method of oxygenator replacement has been described this procedure can be completed in less than 90 seconds without separation for CPB. Requires one replacement oxyenator, one tubing clamp, one pair sterile scissors, and one alcohol wipe. This technique will be demonstrated

Groom RC, Forest RJ, etal; Parallel replacement of the oxygenator that is not transferring oxygen: the PRONTO procedure. Perfusion 2006 21: 297-303


A. GAS SUPPLY PROBLEM DIAGNOSIS (Low PA02 on initiation of CPB)
   Draw ABG
   • Is sensor in line
   • Observe A-V color difference
   • Is Fi02 at 100%
   • Monitor Venous saturations
   • Increase blood flow to a cardiac index of 2.6 LPM
   • Speak with anesthesia about possible increase O2 uptake and anesthetic level
   • Do not clamp the Aorta
   • Turn the cooler heater to recirculation
   Check Fi02 and Oxygen analyzer
   • Does the O2 analyzer and Fi02 setting match
   • Does the gas line pressure gauge register positive pressure when restricted.
   • Is the vaporizer fill cap tight
   Correct method of troubleshooting the gas line circuit
   • Blender imbalance
   • Failure of Sechrist blender/or loss of piped O2/Air
   • Quick/efficient/systematic check of O2 delivery system by clamping at each break in the line. (Review diagram)
   Location of E cylinder of oxygen and appropriate hook up
   • Correct hook up to blender if loss of O2/Air at wall
   • Correct hook up to gas line at oxygenator

B. BLOOD PATH PROBLEM DIAGNOSIS
   Verify correct placement of clamp on oxygenator bridge
   • Why is this important
   Verify that the recirculation line is off or clamped
   • Why is this important
   Verify that the blood in and blood out connections are correct
   • Why is this important
Check the transmembrane pressure delta P

- What should the TMP be for this oxygenator (80-120 mm hg; 20-25 mm hg per liter of flow) This will vary by manufacturer and bubble wrap.
- Would high HCT, high MAP, high flow affect TMP? If yes how?
- The TMP is low (below 100mm hg @>4LPM), PA02 is OK. Are you concerned? What is a possible cause? (Pressure fluid separator dome pressurized, recirculation line open)
- The TMP is normal, the PA02 is high and the Venous saturation is low, (<50%) Color of blood is chocolate brown. What is the possible cause? (Methemoglobinemia) (possible causes-drugs, Nitro, Nipride, Lido) (Rx- stop drugs, give methylene blue 1mg/kg, and if all else fails Blood exchange)
- Sickle cell enemia- how does it manifest itself? (Low Ven Sats, hemolysis, high Ks) (Rx blood exchange)
- Malignant hyperthermia (increased o2 extration and increased temperature to dangerous levels causes- heredity, anesthetic agents Forane) (Rx; turn off drug dantaine 1mg/kg)
- H2O to blood leak?
- The TMP is high, the PA02 is good and the Venous saturation is good. What do you do, how does SVR affect this.
- The TMP is normal, the PA02 is low (<50mm hg), the Venous saturation is low (<50%) what are the possible causes? (non occlusive arterial pumhead or underperfusing the patient)
- The TMP is high (>200mmHg) , the PA02 is low (<50 mm hg), the Venous saturation is low (<50%) What are the possible causes and what do you do.

C. OXYGENATOR CHANGE OUT

Communicates information to all parties

- What do you say
- Can anesthesia help? (Beating heart vs non beating heart)

Follows department protocols for change out

- What supplies do you need and why

DISCUSS OPTIONS FOR CHANGE OUT IF:

A. BEATING HEART
B. ARRESTED CLOSED PROCEDURE
C. ARRESTED OPEN PROCEDURE
Protocol to Correct Poor Oxygenation during Cardiopulmonary Bypass

PURPOSE: The purpose of the following guideline is to assist the Perfusionist in diagnosing and correcting poor oxygenation in a rapid and safe manner.

Poor oxygen transfer may be caused by technical failure of the CPB circuit, failure of the oxygenator, or a hemoglobin disorder.

If poor oxygenation is observed:
1. Call a second perfusionist into the room. Notify the surgeon and anesthesiologist. (DO NOT CROSS CLAMP THE AORTA)
2. Obtain an arterial blood gas and record the venous oxygen saturation.
   a. If the arterial PO2 is normal but the blood appears dark and desaturated, suspect Methemoglobinemia and follow Methemoglobinemia Protocol.
   b. If the Arterial PO2 is low, suspect gas supply problem, CPB circuit blood path problem, or oxygenator failure.
3. Initiate the following steps to improve oxygenation
   a. Discuss increasing anesthetic level with the anesthesiologist to reduce oxygen demand. Close all shunts (filter purge line, hemoconcentrator) and increase the blood flow rate to at least 2.6 L/M².
4. Check the gas supply:
   a. Increase the FiO₂ to 100% and verified the FiO₂ with the oxygen analyzer.
   b. Check the gas supply and verify that it unobstructed and leak free.
5. Inspect the blood path of the oxygenator.
   a. Verify that the bridge around the oxygenator is completely clamped.
6. Transmembrane Pressure measurement.
   a. Place a clamp after the pressure measurement port on the oxygenator bridge and Remove the clamp before the port to obtain the pre-membrane pressure. The pre to post membrane pressure difference should be less than 120mmHG. If the pressure is 120mmHg or more suspect an obstructed oxygenator; replace the oxygenator if the Arterial PO₂ remains below 50mmHg and the venous saturation is less than 50%.
7. Change out the oxygenator according to protocol.
If you determine that there is a leak in the ventilating gas delivery system during the pre-operative checklist. Perform the following steps to isolate and correct the leak in the ventilating gas delivery system.

1. Clamp at point “A”. Pressure gauge should rise rapidly to 300 mm Hg at which time the clamp should be released; you have determined there is no leak in the ventilating gas delivery system between the clamp and the blender. Gas supply integrity is OK. Look for other causes of poor oxygenation if the gauge did not rise rapidly then a leak exists between point “A” and the blender. Continue to step two.

2. Clamp at point “B”. Pressure gauge should rise rapidly to 300 mm Hg at which time the clamp should be released; this indicates the leak is between point “A” and “B”. REPLACE THE GAS FILTER. Re-clamp point “B” again to verify that the leak has been corrected. If the gauge did not rise rapidly then a leak exists between point “B” and the blender. Continue to step three.

3. Clamp at point “C”. Pressure gauge should rise rapidly to 300 mm Hg at which time the clamp should be released; this indicates the leak is between point “B” and “C”. Check that all connections are tight on the O2 sensor; if that does not fix the leak replace the sensor and/or connector. Re-clamp point C again to verify that the leak has been corrected. If the gauge did not rise rapidly then a leak exists between point “C” and the blender. Continue to step four.

4. Clamp at point “D”. Pressure gauge should rise rapidly to 300 mm Hg at which time the clamp should be released; this indicates the leak is between point “C” and “D”. Check to be sure the fill cap of the vaporizer is tight, that the gas in and gas out connections on the vaporizer are tight; if that does not correct the problem; consider a vaporizer internal leak; discuss with anesthesia discontinuing the agent and isolating the leak by turning off the vaporizer. You can isolate the vaporizer completely by disconnecting the inlet and outlet connectors from the vaporizer and connecting them together by placing one inside the other. If the gauge did not rise rapidly then a leak exists between point “D” and the blender. Continue to step five.

5. If step four does not correct the leak, this indicates the leak could be between point “D” and “E”. Check that the tubing connecting the pressure gauge is tight and that the Y is not creaked or broken. If there is still a leak from point “D” to the blender. Continue to step six.

6. If step five does not correct the leak, check that the gas outlet line is tight, if it is then this could indicate a leak in the blender itself; consider the options of replacing the blender, using an alternate gas source; or assuming the PA02s are adequate despite the leak continue to use the blender until after the case. The blender should be evaluated by clinical engineering as soon as possible.