Original Article

Presented at the AmSECT 30th International Conference

March 13-16, 1992, Washington, D.C.

Trouble Shooting the Extracorporeal Membrane Oxygenator Circuit and Patient

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Keywords: extracorporeal membrane oxygenation

Abstract

Patients requiring extracorporeal membrane oxygenation (ECMO) often become totally dependent on the mechanical life support. The Extracorporeal Life Support Organization (ELSO) reports 2486 incidents of mechanical complications in 5905 ECMO supports. To help decrease the number of mechanical complications, an active quality assurance program was initiated at our institution. This resulted in identification of only 14 incidents of mechanical complications in 100 patients (neonate, pediatric, adult, and cardiac). Techniques for dealing with problems such as loss of roller pump occlusion, changing out of the membrane lung or heat exchanger without interrupting ECMO support, venous air lock, tamponade, emergency transfusion, and other situations were generated into written policies and procedures.

We routinely review and practice problem solving techniques with specific emphasis on monitoring patient hemodyanmics and appearance.

We conclude that written policies and procedures, "water drills," and continuing education can be beneficial in early recognition, intervention, and/or prevention of ECMO mechanical complications.

Introduction

Extracorporeal membrane oxygenation (ECMO) utilizes a modified cardiopulmonary bypass circuit to provide extended cardiopulmonary support for patients with severe respiratory and/or cardiac dysfunction. Patients on ECMO support often become totally dependent on ECMO before their cardiorespiratory condition improves. In addition, patients may require ECMO for a protracted illness whereas mechanical complications could prove catastrophic to the patient. The first 100 ECMO supports at our institution were reviewed by the quality assurance committee with special attention to mechanical complications. In this group 14 incidents of mechanical complication occurred; none of which resulted in patient injury. In comparison, the Extracorporeal Life Support Organization (ELSO) reports 2486 mechanical complications during ECMO support of 5905 patients (1). Our techniques for preventing mechanical problems along with trouble shooting protocols represent the basis of this report.

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Materials and Methods

A roller pump and computer[a] were used for ECMO support. Servo-regulation of pump rate was provided by the CAPS unit which monitored pre-membrane and venous pressures. The ECMO circuitry was a modification of that utilized by Bartlett (Figure 1) and was provided in a prepackaged sterile packet[b] (2). Silicone membrane lung and stainless steel heat exchangers[c] were used. Selection of devices was dependent on the size and age of the patient, as well as the specific

a Stockert-Sorin, Irvine CA
b Gish Biomedical, Inc., Santa Ana, CA
c Avecor, Minneapolis, MN

disease process. A water bath[d] was used for warming the blood. A 9.5 mHz Doppler[e] was placed on the venous inflow line just proximal to the venous reservoir. This provided a continuous audible indication of venous return. Cannulae used depended on the site of cannulation and the patient's size. Elecath cannulae[f] were used for most carotid/jugular cannulation while Bard[g] and DLP[h] cannulae were used for most direct aorta/right atrium cannulation. A total of 13,113 hours of ECMO support for 100 patients was reviewed and any mechanical complication analyzed. Particular interest was paid to the following factors; response time, techniques used to correct problems or potential problems, and recommendations to reduce the risk of repeat or future complications. Policy and procedures were then generated and/or updated. These policies were reviewed with the ECMO staff and made available in the ECMO unit.

Results

Roller Pump Occlusion

Sudden loss of roller pump occlusion rarely happens but instead usually occurs over a period of time with several recognizable indicators of decreased forward propulsion of blood. Indications that the roller pump occlusion is not sufficient include an increase in patient pulse pressure despite a negative fluid balance, no displacement of the settled blood in the bridge during opening of the bridge, little change or even a decrease in the venous saturation despite an increase in pump flow, a loss of the continuous Doppler signal, and no servo-regulated shut-off of the roller pump when the venous drainage line is occluded (3,4). Plasma free hemoglobin will increase due to the pooling of blood. Post-membrane pO_2 will remain high as membrane function is preserved by the lack of forward movement of blood. The result will be a patient with mixed metabolic and respiratory acidosis unresponsive to administration of sodium bicarbonate or THAM. The pre and post-membrane pressures will remain inordinately low despite increasing pump flow rates, and normal, or even elevated, mean arterial blood pressure. Venous reservoir pressure will be high and remain so with increases in pump rate. Activated clotting times (ACTs) may have wide fluctuations due to varying heparin delivery to the circuit and patient. Besides the above mentioned circuitry and circulatory changes, loss of roller occlusion can have a profound effect on organ blood flow. Particularly worrisome is the loss of normal Doppler flow patterns on head ultrasound.

Many patients on ECMO support are totally dependent on

d Seabrook Inc., Cincinnati, OH
e Parks Inc., Oloha, WA (isn't this Aloha, OR?)
f Electro-Catheter Corp., Rahway, NJ
g C.R. Bard Inc., Billerica, MA
h DLP, Grand Rapids, MI

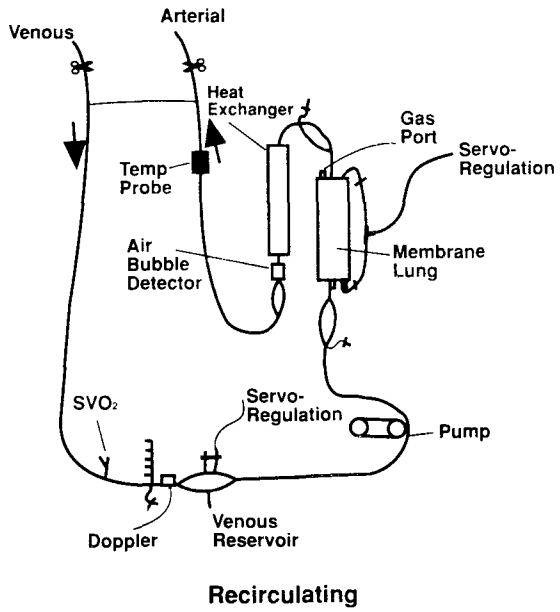

Figure 1
Standard ECMO circuit and components.

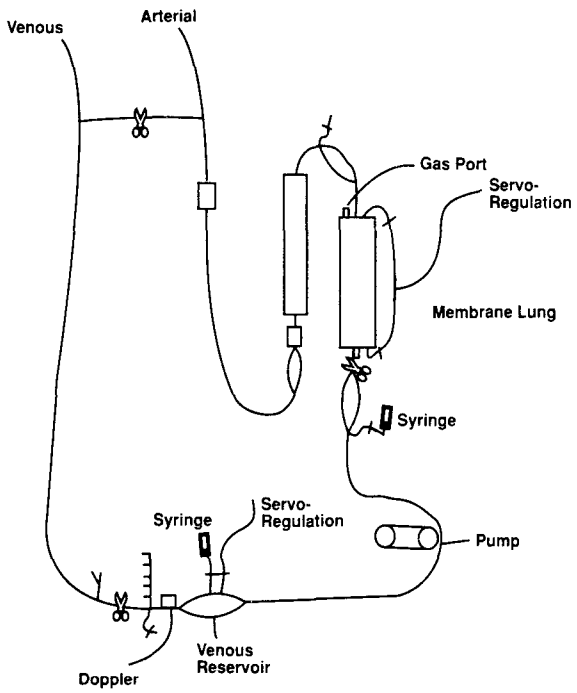

Figure 2
Isolation of roller pump head to set occlusion with two columns of fluid; one column at the ACT port and the other at the venous reservoir.

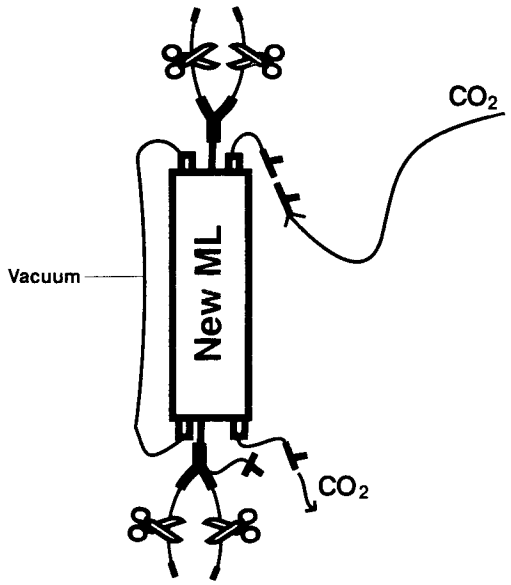

Figure 3-A
CO_2 flushing of replacement membrane followed by vacuum attachment.

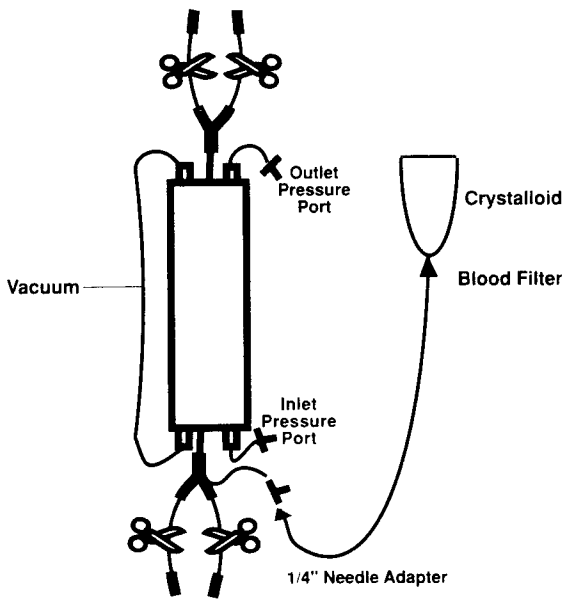

Figure 3-B
Attachment of crystalloid to ACT port to begin fluid priming of membrane lung and tubing.

ECMO for a period of time. Thus they may not tolerate being off ECMO for the time it would take to correct faulty occlusion by standard techniques. In such a situation, the venous line Doppler can be used to monitor adjustments to the occlusion. To do so the occlusion setting mechanism on the pump is tightened until a distinct "swishing" sound is heard from the Doppler. The occlusion is then backed off slowly until the sound just begins to fade. The occlusion is slowly tightened once again until a stronger Doppler sound is audible, indicating proper occlusion. Practice of this maneuver in the laboratory is imperative. Once the patient is able to be supported without ECMO briefly, the occlusion is re-checked with a column of fluid. When reducing the flow to facilitate adjustment of the roller occlusion it is necessary to increase mechanical ventilation to attempt to assist with oxygenation. Once occlusion is satisfactory, the pump rate can be increased to the appropriate level.

If the patient is able to tolerate being off ECMO support, occlusion can be set with a column of fluid. To do so, 50 ml syringes without plungers are attached at the ACT port and the extra bladder port. Approximately 10 ml of sterile fluid is placed in the syringe on the ACT port. The patient is hand ventilated with 100% oxygen and the roller pump is slowly turned down and finally stopped. The roller should be at the back wall of the roller pump casing. Clamps are applied between the ACT port and the entrance to the membrane lung and just proximal to the bladder. The stopcocks are opened and the occlusion is adjusted (Figure 2). The height between the two columns of fluid is approximately 20 inches. Acceptable occlusion is indicated with a drop in the column of fluid at a rate of 1 ml/min. with blood in the circuit tubing. Both stopcocks are turned off and the clamps removed. Pump flow is reinitiated and increased. The patient is stabilized, the ventilator settings are returned to resting parameters. Some volume replacement may be necessary due to the release of pressure in the venous reservoir when the stopcock was opened.

Membrane Failure

Membrane failure may happen at any time during ECMO support. Just as the time frame of membrane failure may vary so may the causes for the failure. Any failing membrane should be changed immediately upon recognition. A tear in the membrane between the blood path and the gas path will result in pink or red condensation blowing out of the gas outlet port or gas emboli appearing post-membrane. Which feature predominates will depend on the relative pressures in the blood/gas compartments of the membrane lung. The most dangerous membrane failure is the gas to blood leak resulting in possible gas embolus to the patient, although in our experience and communication with other ECMO centers most ruptures appear as a blood to gas leak.

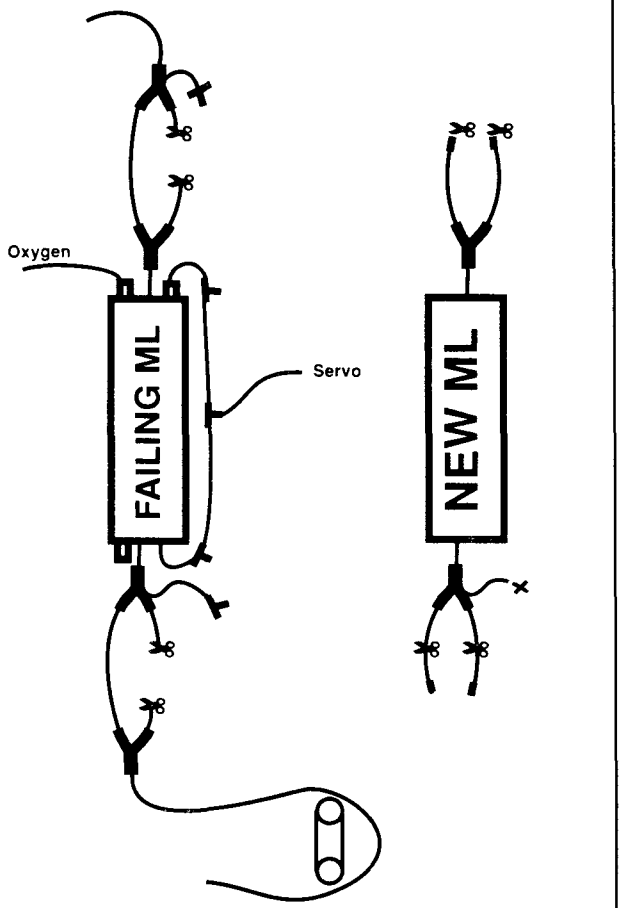

Figure 3-C
Clamping and cutting of failed membrane loops for placement of replacement membrane lung.

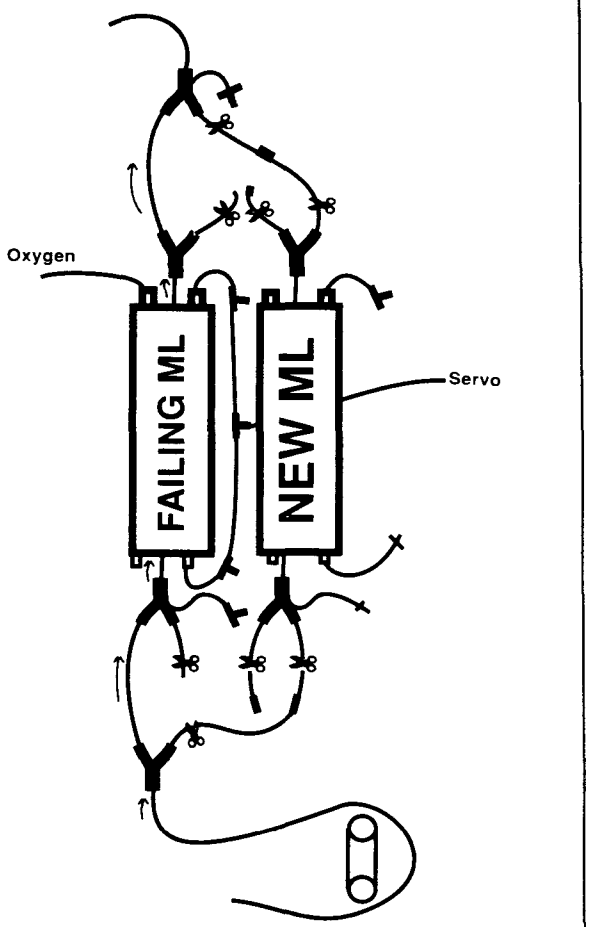

Figure 3-D
Replacement membrane in-line.

A blood to gas leak usually becomes apparent during the hourly check of the gas exhaust port by the technician. The location of the rupture can be important. We have found if the condensation appears to be of blood consistency the tear is close to the gas outlet port tubing of the membrane gas compartment, and can result in gas outlet port clotting off. This is possibly due to a shorter distance to travel resulting in very little mixing with water vapor from the sweep gas. In ruptures further from the port the condensation from gas flow through the membrane appears to dilute the blood and reduce the risk of clot.

To facilitate membrane change out, sterile individually wrapped pieces of tubing and connectors are readily available. This allows rapid priming of a replacement membrane. Utilizing sterile technique, the appropriate size membrane assembly is prepared by attaching tubing to the blood inlet and outlet ports. These lines are then clamped. Two stopcocks are fastened to the end of a single 6 inch male to female extension tubing previously attached to the post-membrane pressure port (Figure 3-A). Another stopcock and a 6 inch male to female extension tubing is attached to the pre-membrane pressure port. The stopcocks are opened and CO_2 flow is initiated through the membrane via the double stopcocks in the post-membrane position. CO_2 is started at a flow of 1 L/minute. After 2-3 minutes of CO_2 flow, each clamp is individually released for one minute to allow purging of air from that portion of the tubing. The clamp is reapplied, and this maneuver is performed until all four clamps have been released and reapplied. Vacuum at a rate of -5 to -10 mmHg is then applied to the gas inlet and gas outlet ports. The negative vacuum pressure should not exceed the CO_2 gas flow rate. If the sound of CO_2 exiting the membrane is not present at the pre-membrane pressure port, air could be aspirating into the membrane lung. The membrane lung is CO_2 flushed for at least 5 minutes. When the CO_2 flushing is completed it is important that the pre- and post-membrane pressure stopcocks be turned off simultaneously. Failure to do so may result in air being aspirated into the blood compartment of the membrane, making priming more difficult. Crystalloid is attached to a blood filter and tubing which has a "1/4 inch to needle adapter" at the other

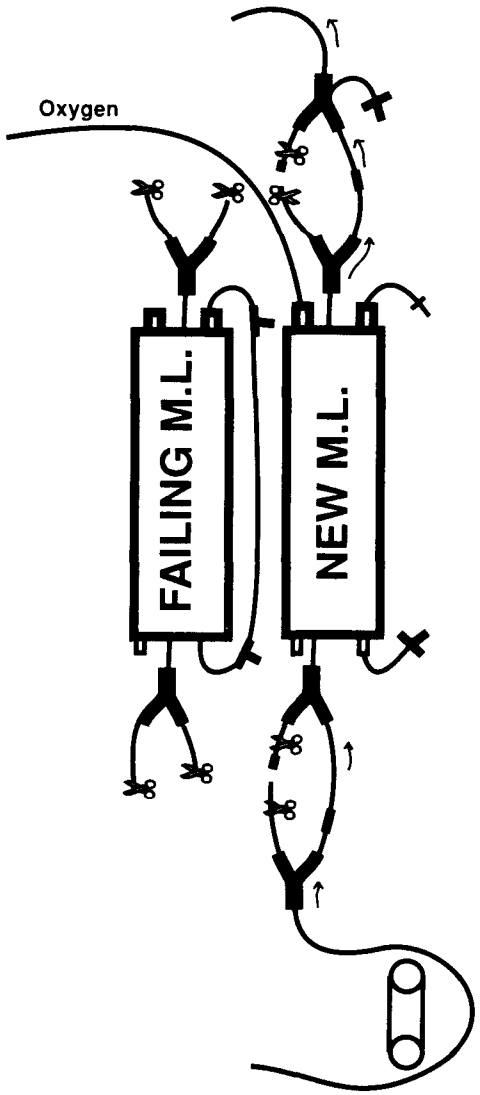

Figure 3-E
Failed Membrane removed from circuit and reattachment of loops.

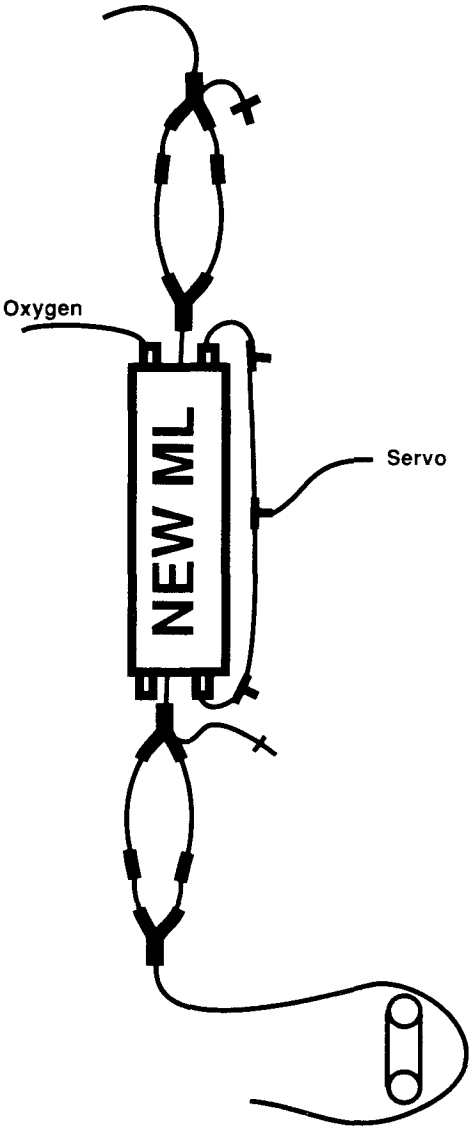

Figure 3-F
Reactivation of pressure servo-regulation to membrane.

end. All gas is evacuated from the crystalloid bag and tubing. (Figure 3-B)

The crystalloid is attached to the blood inflow side of the membrane lung via the needle adapter and stopcock at the ACT port. The stopcock is opened and the membrane lung filled. Each piece of tubing on the pre-membrane side that has a clamp applied to it is opened briefly to allow fluid to fill into the tubing. The clamp is then reapplied. When fluid is seen reaching the outflow portion of the membrane lung, the clamp on one of the pieces of tubing on the outflow side is opened. Following reclamping of this tubing the other piece of tubing on the outflow side is opened to once again allow air to be evacuated. The stopcock attached to the post-membrane pressure tubing is opened briefly to evacuate any air which may be trapped at the top portion of the membrane lung. When the membrane and lines have been flushed with approximately 500 ml of crystalloid, the clamp on the crystalloid flush line is reapplied. Using sterile technique 50 ml of 5% albumin is added to the remaining crystalloid in the bag and mixed. Each clamp on the limbs will be opened and reclamped again allowing the crystalloid/albumin mixture to flush through the

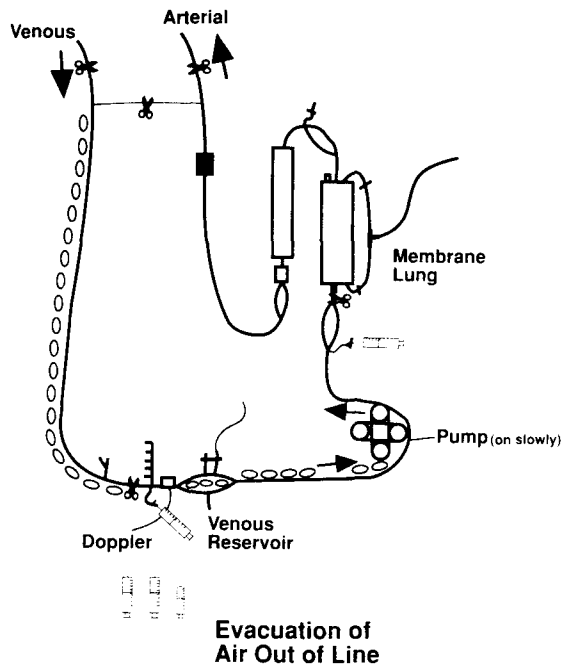

Figure 4-A
Removal of air in venous line utilizing infusion of blood into reservoir and aspiration of air at ACT port.

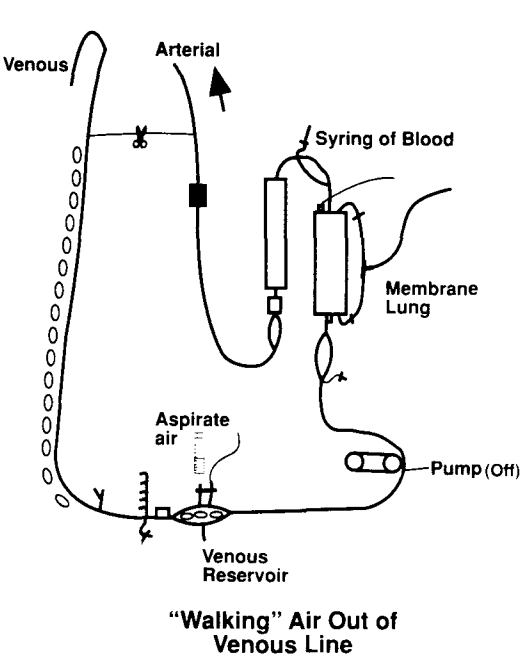

Figure 4-B
Evacuation of remaining air in venous line at port of venous reservoir.

tubing and membrane lung. The last clamp, which should be on the outflow side of the membrane, will be left open allowing the remaining crystalloid/albumin mixture to coat the membrane. After this is completed the clamp is applied to the outflow tubing and a clamp is applied just beyond the blood filter.

Next, 100 units of beef lung heparin, 50 ml of 5% albumin, and 50 ml of THAM are added to one unit of packed red blood cells which is then attached to the blood filter. The stopcock is opened and gentle pressure placed on the blood bag. The clamps on the inflow portion of the tubing are once again opened and reclamped one at a time allowing blood to displace the crystalloid. One clamp on the outflow side of the membrane is opened and the crystalloid in the membrane is replaced with packed red blood cells. As the blood exits the membrane the vacuum on the gas inlet port is removed and clamped, facilitating the aspiration of air across the gas compartment. The resultant change in color of oxyhemoglobin in the blood solution is known as a positive "pink test." A second clamp is reapplied to the tubing and the remaining portion of tubing containing crystalloid is unclamped and reclamped to allow filling with blood. Once the membrane and all four pieces of tubing are filled with blood the stopcock is turned off and disconnected. The vacuum on the gas outlet port is also disconnected. The replacement membrane is moved to the ECMO circuit and beside the existing membrane (Figure 3-C).

The loop lines on both the inflow and outflow of the failed membrane are prepped with betadine and double clamped. Adhesive tape is wrapped around each clamp to insure no accidental de-clamping once the loop line has been cut. Both pre and post-membrane loops are cut and the appropriate line of the replacement membrane is attached with special attention to evacuate any air (Figure 3-D). Once the membrane is secured in the ECMO circuit the clamps are removed, and blood is allowed to flow through the new membrane. The sweep oxygen line is then moved to the new membrane lung. Double clamping of the loop lines of the failing membrane is performed again utilizing the adhesive tape safety feature (Figure 3-E). Betadine prepping of the tubing, cutting of the loop line, and reattachment of the loop line to the new membrane complete the change out. Servo-regulation is re-engaged by attaching the appropriate transducer lines to the stopcocks on the pre-and post-membrane monitoring lines (Figure 3-F). The transducer should be re-zeroed and recorded. The failed membrane should be returned to the manufacturer and reported to the Food and Drug Administration.

Faulty Heat Exchanger

A faulty heat exchanger may cause a blood-to-water or water-to-blood leak. A blood-to-water leak is usually easily

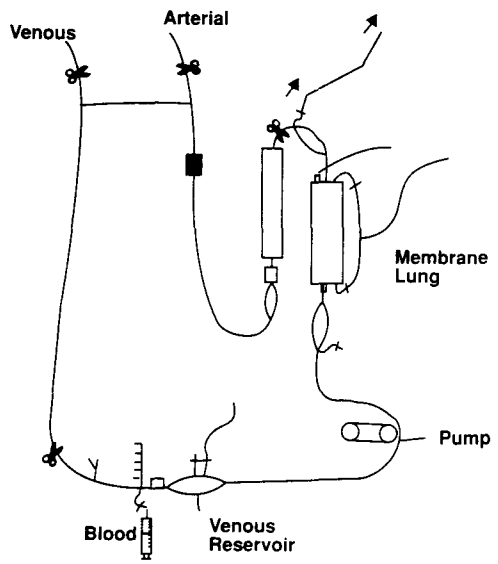

Figure 5-A
Transfusion via extension tubing to central line of patient.

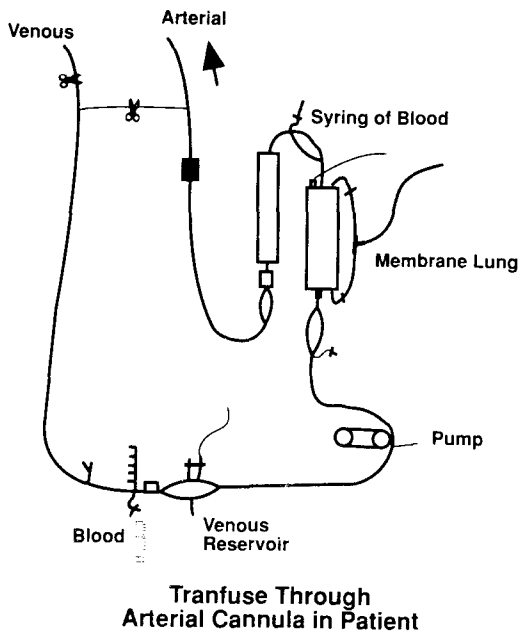

Figure 5-B
Transfusion with only arterial cannula in place.

detected by blood coloring the water bath. A water-to-blood leak is harder to detect. Early indications will be a drop in hematocrit or an increase in the patient's cardiac ejection, hematuria, and positive blood cultures. This is demonstrated by a wider pulse pressure in the arterial pressure curve due to an increase in blood volume when, ostensibly volume has not been added to the circuit. An audible sound may also be heard from the air bubble detector without the pump stopping indicating micro emboli or sudden changes in blood viscosity.

All faulty heat exchangers must be changed immediately. To do so, the water bath is immediately turned off. If the leak is water-to-blood, turning off the water bath may reverse the leak to a blood-to-water leak by decreasing the pressure on the water bath side. The cap on the water bath should be opened to avoid pressurizing the water bath unit thus returning the leak to a water-to-blood leak. A raceway (1/4" tubing with 1/4" straight connectors at each end) should be filled with crystalloid and clamped at each end. The loop lines on the inflow and outflow sides of the heat exchanger are clamped and adhesive tape applied as previously described. The loop lines are betadine prepped and cut. The raceway is attached to each end of the cut loop line. Clamps on the raceway loop lines are removed at the same time as clamps are placed on the faulty heat exchanger loop lines to establish a blood flow path around the heat exchanger. This insures no pressure changes in the circuit which could cause reversal of the water shunt, although the patient may cool slightly due to temporary loss of the heat exchanger.

After securing the temporary bypass of the heat exchanger a new heat exchanger is prepared. Circuitry tubing is attached to a new heat exchanger. A new water bath is connected to the new heat exchanger, turned on, and checked for leaks. Crystalloid prime is attached to the stopcock as previously described and allowed to fill the inverted heat exchanger. If the patient is not cooling rapidly, heparinized packed red blood cells should be used as previously described to evacuate the crystalloid. However, if the patient is cooling rapidly the heat exchanger can be placed back into the circuit filled with only crystalloid. The faulty heat exchanger loop lines are prepped with betadine, cut, and reattached to the new heat exchanger with special attention to air evacuation. Once incorporated into the ECMO circuit, the clamps are removed from the heat exchanger loop lines, and applied to the raceway loop lines. The raceway is removed from the circuit and loop lines reattached to the remaining heat exchanger loop lines to complete the circuitry. All faulty heat exchangers should be reported immediately to the manufacturer and returned.

Venous Air Lock

Venous air lock usually results from dislodgement of the venous cannula so that one or more of the side holes is outside

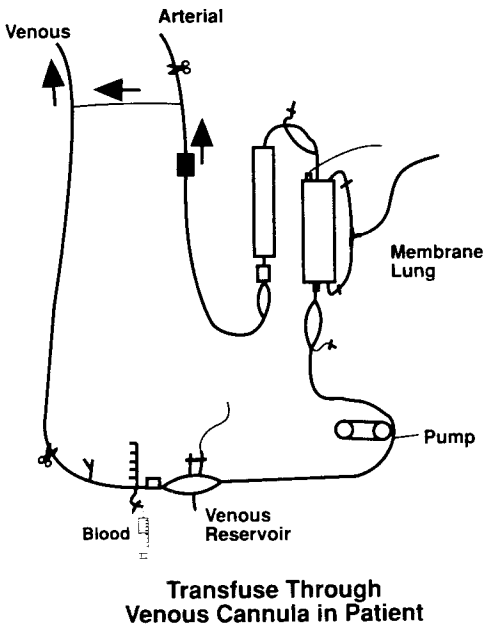

Figure 5-C
Transfusion with only venous cannula in place.

the vessel. If the cannula has slowly worked its way out of the vessel a small amount of air may be seen steadily entering the venous reservoir. The Doppler on the inlet portion of the venous reservoir will indicate even small amounts of air in the venous line, by a distinctive sharp crackling sound (3). The patient's blood pressure may increase with the pressure curve showing increased ejection. As the patient may have to be taken off ECMO support, hand bagging should begin with 100% FiO_2. Early detection of venous air lock by the Doppler may help the technician maintain ECMO support, but at a lower blood flow, provided no air reaches the roller pump. The venous cannula is pushed gently back into the vessel. For small amounts of air in the venous line, the technician can "walk" the air down to the venous reservoir by sequentially raising the venous line while a second person aspirates the air out of the reservoir. Massive airlock which results in air in the raceway requires the patient to come off ECMO support. To correct such a situation two 50 ml syringes one empty and one filled with crystalloid or blood are needed. Clamps are placed proximal to the venous reservoir and just before the membrane lung. The syringe with fluid is attached to the infusion port of the venous line and the empty syringe is attached to the ACT port. Fluid is infused into the venous reservoir while the stopcock of the reservoir is opened to displace air from the reservoir. Once the venous reservoir is refilled with fluid the pump is turned on slowly and the ACT port stopcock opened. Fluid is added to the reservoir as the air is pushed forward and removed at the ACT port (Figure 4-A). This maneuver is repeated until the raceway and tubing leading to the membrane are free of air. The clamps at the inlet to the venous reservoir and membrane lung are removed. The patient is placed back on ECMO support but at a lower blood flow until any remaining gas in the venous line is "walked" to the venous reservoir and aspirated as previously described (Figure 4-B). Small amounts of air that pass into the membrane lung or heat exchanger can be aspirated via stopcock. The patient's hematocrit will fall but this can be corrected once back on ECMO support.

Tamponade

Most tamponades occur in post-operative cardiac patients. However, there have been reports of patients having cardiac tamponade during ECMO support. At our institution the chest incision remains open, covered with iodionized plastic adhesive in almost all cardiac ECMO patients (5). Routine reexploration is performed every 24-36 hours to insure that tamponade does not occur. However, tamponade has occurred due to Surgicel[i] packing on the posterior aspects of the heart. Visual inspection will show no pooling of blood around the heart. Indications of tamponade include sudden loss of venous return (even with pump flow reduced slightly), rising atrial pressure, dropping blood pressure, and a rhythmic thumping at approximately the heart rate. The physician should be summoned immediately. A sterile reoperative tray along with a chest retractor should be at the bedside at all times. Removal of the plastic adhesive covering the incision must be accomplished with extreme care so as not to dislodge cannulae, pacemaker wires, or atrial pressure tubing. Usually a finger sweep of the posterior region of the heart will relieve the tamponade immediately. Venous return rapidly returns to normal and pump flow may be increased to previous level. Once the reexploration is completed the chest is redressed with another piece of iodionized plastic adhesive.

Emergency Transfusion

Patients being placed on ECMO support may further deteriorate when anesthetized for cannulation. Decreasing blood pressure or loss of blood during actual cannulation may necessitate infusions for volume expansion. Transfusion of warm, oxygenated blood from the ECMO circuit can be performed if the patient has a central line or if either of the cannulae are in place. Blood left in the priming reservoir is drawn into two 50 ml syringes once the tubing is clamped beyond the bridge. One syringe of blood is attached to the med-infusion port. The arterial and venous line will be discon-

i Johnson & Johnson Medical Inc., Arlington, TX

nected from the priming reservoir and taken to the sterile field in preparation for connection to the appropriate cannula. If the patient has been extremely unstable a section of large bore pressure tubing is connected to the platelet infusion stopcock. The pump is turned off and a clamp applied just before the heat exchanger. A second clamp is applied on the inflow tubing to the venous reservoir. The pump is slowly turned on as the platelet infusion stopcock is opened. This allows filling of the extension tubing. Should the venous reservoir empty enough to alarm the CAPS, extra volume may be added by opening the med-infusion stopcock and infusing volume from the syringe of blood. Once the pressure tubing is free of air, the pump is turned off as well as the platelet stopcock. The clamps on the venous line as well as the clamp before the heat exchanger are removed and recirculation resumes. The male end of the pressure tubing is attached to a stopcock on the central line. Should the patient require volume, the pump will be turned off, clamps applied as previously described, and the platelet infusion stopcock and central line stopcock opened (Figure 5-A). The pump is then turned on very slowly infusing blood to the patient. If more volume is needed than is available in the reservoir, the med-infusion stopcock can be opened and volume from the syringe infused into the reservoir. Pre-membrane pressure will indicate if the pressure is becoming too high in the central line. Once adequate volume status is reached, both stopcocks are turned off and both clamps removed to allow recirculation of blood through the ECMO circuit.

The arterial cannula is usually inserted first. If there is anticipated venous cannulation difficulty, the arterial tubing from the ECMO circuit is immediately attached to the arterial cannula. The arterial cannula can then be used for transfusions directly into the aorta by stopping the pump, clamping the bridge, and releasing the arterial clamp (Figure 5-B). The pump is then turned on slowly. If more volume is needed, the syringe of blood at the med-infusion port is used to fill the venous reservoir. Once transfusion requirements are met, the pump is stopped, the arterial tubing is clamped beyond the bridge, the clamp on the bridge is released, and the prime recirculated.

During decannulation there may arise a situation that necessitates removal of the arterial cannula before the venous cannula. If the need for transfusion arises, but the arterial cannula has been removed, volume can be transfused via the venous cannula as long as a clamp is applied just before the venous reservoir. The clamp on the venous line beyond the bridge is removed, and the pump is turned on slowly (Figure 5-C). Any additional volume that is needed can be added as previously described. Once the transfusion is completed the pump is turned off, a clamp is applied to the venous line beyond the bridge, the clamp on the venous line just proximal to the reservoir is removed, and recirculation initiated.

Routine decannulation allows the arterial cannula to remain in place while the venous cannula is removed. We have found that once the venous cannula has been removed the volume in the venous line may be used to transfuse the patient. The pump is stopped, a clamp applied to the bridge, the clamps on the venous and arterial lines are removed, and the pump started slowly. Once sufficient volume is transfused to the patient the pump is stopped, the arterial line clamped, and the cannula removed. Should the patient require volume expansion after this, the previously noted method utilizing pressure tubing from the platelet port to central line can be performed.

All transfusion methods should be used with care due to the possibility of intracardiac shunts that more than likely are in a right to left flow pattern when cannulating. Any gas emboli even in the central line could very easily enter the aorta and result in catastrophe. Monitoring pre membrane pressure will help the technician not to over pressurize the ECMO circuit or damage a blood vessel of a heparinized patient. The venous pressure as well as the low level alarm on the reservoir will protect from cavitation due to lack of reservoir volume.

Changing of ECMO Circuit

The entire ECMO circuit is changed out every 7 days unless the patient is anticipated to come off support during days 8 or 9. An entire circuit is assembled and primed. If the patient requires inotropic drugs during the support they will be infused directly into the patient rather than the circuit. The arterial and venous lines are prepped with betadine at the cannulae-circuit connectors. Clamps are placed in the ready position between the proximal end of the cannulae tubing and just beyond the 1/4" straight connector and the bridge. The ECMO circuit is allowed to recirculate while two syringes of blood are harvested from the priming reservoir. One syringe is placed on the platelet infusion port of the fresh circuit to be used for volume replacement while the other is taken to the sterile field where the cannulae will be reattached to the fresh circuit. A blunt 18 gauge needle is attached to this syringe to reduce bubbles and foam when evacuating air at the connection site. An ACT is performed just before the circuit is changed out.

Strict sterile technique including gown, mask, gloves, and eye protection is used during the procedure as this maneuver should be viewed as entering the patient's body. The patient is ventilated by hand with 100% oxygen, the pump flow is turned down very quickly until the patient is off ECMO support. The previously described clamps that were already positioned are clamped and the arterial and venous lines are cut with a sterile blade. The arterial line is attached first with extreme care that all air is removed. The venous line is attached second. Any gas emboli in the venous line can be trapped and evacuated from the venous reservoir. During this procedure the technician manning the pump removes the oxygen line and positions

himself behind the newly primed pump and circuit. Once arterial and venous cannulae are attached to the fresh circuit the arterial clamp is released, the bridge is clamped, and the venous clamp is released. The oxygen line is attached to the gas inlet port and the pump flow is increased. Volume may be infused to treat hypovolemia. The syringe of blood attached to the platelet infusion port is opened and oxygenated packed red blood cells infused. The infusion manifold from the old circuit is moved over to the new circuit and inotropic infusions are relocated back to the circuit.

A unit of 3-5 day old platelet pheresis is infused through the platelet infusion port within the first 30 minutes after replacing the circuit. Fifty ml of blood from the old circuit is harvested and preserved at -70° C for any future evaluation. The old circuit is dissected and any findings are reported to the physician and recorded in the patient chart.

ECMO Staffing

In our institution, when mechanical problems with ECMO support occurred, an ECMO coordinator was always able to respond within five minutes or less. During all mechanical complications the ECMO technicians were able to maintain the patient on ECMO support until the coordinator was in the ECMO unit. One patient that had a mechanical complication did expire at termination of ECMO support. The mechanical complication was not a contributing factor to the patient's demise.

The ECMO team completed didactic, water drills, and animal laboratory education with special emphasis on recognizing mechanical complications. The team members served a preceptorship following passing of a written and timed oral examination. Yearly recertification by written and oral examination remains mandatory. ECMO technicians must complete one 8 hour shift as primary technician every month or repeat the preceptorship. Continuing education consists of journal club, water drills, and national/international meetings. A mechanical troubleshooter specialist was in-house at all times. A physician remains in-house until the patient stabilizes, usually within 12-24 hours. A certified clinical perfusionist is either in-house or within 10 minutes of the ECMO unit. All complications are reviewed by the ECMO staff, hospital mortality/morbidity conference, ECMO mortality/morbidity conference, and quality assurance committee. ECMO team meetings and a monthly newsletter address changes in policies and procedure. We believe that these procedures and the written policies and procedures available in the ECMO unit for emergency reference have lessened our incidence of mechanical problems.

Conclusion

ECMO can be a life-saving modality of treatment for patients with severe respiratory and/or cardiac diseases. Because ECMO usually involves long-term support, mechanical complications and changes in patient condition will be likely. Recognition of and early intervention for complications before they become life threatening can be accomplished by developing and practicing written trouble shooting policies and procedures.

Acknowledgement

The authors would like to express their gratitude to the ECMO technicians, physicians, and hospital administrators of Arkansas Children's Hospital for their support and dedication which has made the contents of this paper possible. A special gratitude is extended to Dr. James Fasules for assisting in the organization of the paper and to Samantha Williams for preparation/typing of the paper.

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