CHAPTER

110

Extracorporeal Circulation for Respiratory or Cardiac Failure

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INTRODUCTION

You probably turned to this chapter because you are caring for a patient with acute heart or lung failure, and the patient is failing despite your best treatment. The risk of death for your patient is over 80%, any way you measure it. The patient might be a woman with pneumonia, a child who cannot come off cardiopulmonary bypass, a man with acute respiratory distress syndrome (ARDS), or an emergency department (ED) patient undergoing cardiopulmonary resuscitation (CPR). Your only option to improve survival is extracorporeal life support (ECLS) with mechanical artificial organs.

ECLS is the use of an artificial heart (pump) and lung (membrane oxygenator) to replace organ function for days, weeks, or months to allow time for diagnosis, treatment, organ recovery, or organ replacement. The indications for ECLS are acute, severe heart or lung failure, not improving with conventional management. In a patient with an 80% to 100% risk of dying, the healthy survival results with ECLS ranges from 40% in cardiac arrest with CPR to 95% in neonatal meconium aspiration. ECLS is routine treatment in every major neonatal intensive care unit (ICU) and pediatric cardiac surgery program. Why is ECLS not used routinely in every adult ICU and emergency room? The reasons have been complexity, expense, the need for special equipment and experienced personnel, and education. Improvements in the technology for ECLS are changing this landscape.

BACKGROUND

The heart–lung machine was developed by John Gibbon, culminating in the first successful heart operation using a heart–lung machine in 1954 (1). Dr. Gibbon’s motivation was to develop a technique to treat massive pulmonary embolism, but what resulted instead was the entire field of intracardiac surgery. The artificial heart was simply a blood pump, and the artificial lung was direct exposure of the flowing blood to gaseous oxygen. For cardiac surgery, all the venous return is diverted into the machine and pumped into the systemic circulation, leaving the heart empty long enough to complete the operative procedure. The opportunity to operate directly on the heart was miraculous, but the heart–lung machine itself caused damage to the blood, resulting in fatal complications when used for more than 4 hours. The major cause of blood damage was the direct exposure of blood to gas (2,3). Interposing a gas exchange membrane of plastic (4) or cellulose (5) between the flowing blood and the gas solved most of the blood-damage problems. Silicone membranes became available in the 1960’s and artificial lungs with clinical application were designed and studied (4–10). By eliminating the gas interface it was possible to use a modified heart–lung machine for days at a time, and the physiology and pathophysiology of prolonged extracorporeal circulation were worked out in the laboratory (11–13).

The first successful use of prolonged life support with a heart–lung machine was conducted by J. Donald Hill and colleagues in 1971 (14). The patient was a young man suffering from ARDS, a newly recognized entity at that time; at the same time, the discipline we call critical care was evolving. After Hill’s case, several other successful cases were reported in children and adults with severe pulmonary and cardiac failure (15), and extracorporeal support looked like it might be the answer to the epidemic of ARDS. A multicenter clinical trial of prolonged extracorporeal circulation for adults with ARDS was commissioned by the National Institutes of Health in 1975. This was the first prospective randomized trial of a life support technique in acute fatal illness in which the endpoint was death. There were many problems with the design and execution of that clinical trial, but from it we learned that the mortality for all patients with ARDS was 66%, and the mortality for severe ARDS was 90%, with or without ECLS. We learned that extracorporeal support attempted by inexperienced teams, in venoarterial (VA) mode for 1 week without protecting the lung from ventilator injury, did not improve the ultimate survival in severe ARDS. We learned (the hard way) the mistakes to avoid when conducting a prospective trial in acute fatal illness. And finally, we developed a name for the technology: extracorporeal membrane oxygenation (ECMO).

The results of that study were published in 1979 (16). Laboratory and clinical research on ECLS in adults essentially stopped for a decade because of those results. However, the results in neonatal respiratory failure were very encouraging.

We reported the first successful case of ECLS for respiratory failure in a newborn infant in 1976 (17). Our laboratory had been studying membrane oxygenator development and prolonged extracorporeal circulation in animals for 10 years. We, and others, had used extracorporeal support for postoperative cardiopulmonary failure in children with the first successful pediatric cardiac case in 1972 (18), and we treated 40 newborn patients over the next 5 years with 50% survival (21). Neonatologists and surgeons from other institutions joined us to learn the technology; by 1986, 18 neonatal centers had successful ECMO teams (22).

Our group conducted the first prospective randomized trial of ECMO in neonatal respiratory failure, using an adaptive design to correct some of the mistakes we had made in the earlier adult trial (23). Another prospective randomized trial was carried out by O’Rourke et al. (24) at the Boston Children’s Hospital. ECMO became standard treatment for severe neonatal respiratory failure by 1986, and standard treatment for severe cardiac failure in children by 1990.
Kolobow (25) showed that high ventilator inspiratory pressure (lung stretch) and high \( \text{FiO}_2 \) caused severe lung injury. Gattinoni et al. (26) and Kolobow (25) separated respiration from oxygenation by removing \( \text{CO}_2 \) by extracorporeal membrane oxygenation by insufflation. Using extracorporeal \( \text{CO}_2 \) removal, they prevented stretch injury, and reported 56% survival in severe ARDS. These observations led to renewed interest in ECLS for adult respiratory failure. By the 1990s, several groups reported similar results (27–29). The value of avoiding lung stretch injury has been verified in many studies (30–32), decreasing the incidence of iatrogenic lung injury (and decreasing the need for ECLS). Even with these and other improvements, the mortality for ARDS in otherwise healthy patients was still 30% (32) and ECLS use related to ARDS remained limited to few expert centers.

ECLS technology continued to evolve with the most significant developments occurring in pumps, oxygenators, and cannulae. Centrifugal pump design addressed heat generation and blood stasis, resulting in minimal pump-related hemolysis. Oxygenator design shifted toward polymethylpentene (PMP) membranes which allowed for decreased blood path resistance, improved gas exchange characteristics, and prolonged reliable use. New, dual lumen cannulae came to the market place making practical single-site cannulation for adult veno-venous (VV) bypass. These technological advancements also began to change the bedside model of care. Historically, the complexity of the technology obligated the bedside presence of a technology “specialist”; the modern ECLS technology is simpler to operate and more reliable. In essence, the technology has an improved “safety profile.” This has made practical ECLS bedside care by the experienced critical care nurse with support from the technology “specialist” (33).

While interest in adult ECLS was reinvigorated by these technological advancements, real excitement was generated by two events in 2009: The publication of the CESAR Trial (34) results and the coincidental H1N1 Influenza A pandemic. The CESAR Trial (Conventional Ventilatory Support versus Extracorporeal Membrane Oxygenation for Severe Adult Respiratory Failure) was conducted in the UK from 2001 to 2006 and evaluated a strategy of adult ARDS management that compared transfer to a single center (Glenfield Hospital, Leicester) with ECLS capabilities to a control group of patients managed locally with conventional means. Primary endpoints were mortality and disability at 6 months; 90 patients were randomized to each group. The Glenfield group had 63% (57/90) alive without disability at 6 months compared with the control group that had 47% (41/87) without disability at 6 months. ECLS was used for 68 (75%) of the Glenfield patients, while 16 were managed with conventional means; 5 died prior to arrival. The control group was managed at multiple participating centers without an agreed-upon protocol for conventional care. Glenfield, as the expert center, had access to ECMO but also had a fixed protocol of care. Detractors argued that the intent-to-treat analysis and lack of protocols for critical care and ventilator management in the control centers weakened the conclusions (35).

Early in 2009, there was the emergence of a new H1N1 virus causing an influenza pandemic and the World Health Organization estimated that there were over 200 million cases (36). Early reports described a severe form of hypoxic–hypercarbic respiratory failure, predominantly in young patients, also seen in the obese and pregnant women. Patients were refractory to conventional management with mechanical ventilation, so ECMO was offered as “rescue therapy.” As the pandemic circled the globe, from the southern to the northern hemisphere, reports began to emerge. Australia and New Zealand reported 68 patients supported with ECMO with 75% survival (37). Italy reported the collective of 14 ECMO centers with 68% survival to discharge in H1N1 ARDS patients supported with ECMO (38). Similar reports came out of England, France, and the United States (39–42). CESAR and ECMO use in H1N1 adult ARDS, coupled with modern ECLS technology, changed the landscape of ECMO practice across the world.

The use of ECMO allows study of patients who would otherwise have died, unveiling many aspects of respiratory pathophysiology and treatment. As the technology developed, it was standardized, disseminated, studied, and improved in an organized fashion by the actual users of the technology. This group of investigators and clinicians organized as the Extracorporeal Life Support Organization (ELSO) in 1989. For the last 27 years, this group has developed guidelines, published the standard textbook in the field (43), and maintained a registry of ECLS cases.

### ECLS Technique and Physiology

ECLS is simply the use of a modified heart–lung machine to provide gas exchange (and systemic perfusion if necessary) to prolong the life of a patient when native heart and lung function is not adequate to sustain life. The technique, indications, methods, and results are described in detail in the book ECMO: Extracorporeal Cardiopulmonary Support in Critical Care published by the ELSO (https://www.elso.org) (43). The heart–lung machine used for cardiac surgery is modified, both in devices and technology, to be used for days, weeks, or even months in the ICU. The technique is invasive and complex. A large (23 to 31 French catheter) is inserted into the inferior vena cava or right atrium; venous blood is drained, passed through an artificial lung, and pumped back into the patient, either into the aorta (VA bypass) or into the right atrium (VV bypass). VA bypass puts the artificial lung in parallel with the native lungs and substitutes for both heart and lung function. In VV bypass, the artificial lung is in series with the native lungs and the patient is reliant on his own hemodynamics for pulmonary and systemic perfusion. ECLS allows decreasing the ventilator to nondamaging “rest” settings (typically \( \text{FiO}_2 \) 0.3, pressure 20/10, rate 4), decreasing vasoactive drugs, and optimizing other aspects of treatment.

Because the surfaces of the extracorporeal devices are plastic, it is necessary to anticoagulate the blood; this is most commonly done with a continuous infusion of heparin. Heparin is titrated to a low, but constant, level of anticoagulation and can be measured by whole blood activated clotting time (ACT) with the goal being 1.5 times normal. While this level of heparinization prevents thrombosis in the circuit, platelets still adhere to the plastic surfaces, becoming activated. The platelets then aggregate, break free into the circulation, and are removed by the reticuloendothelial system. Because heparinization and thrombocytopenia are necessary components of ECLS, the major risk of this mode of therapy is bleeding.
Significant bleeding is rarely a serious problem, but it does require a protocized strategy of measuring coagulation profiles and platelet count, titrating heparin dose and platelet infusions accordingly. Properly managed, ECLS can be used for weeks without hemolysis, device failure, clotting, or bleeding. The technology must be learned and practiced by the ICU team and also endorsed by the entire hospital. Management of the patient during ECLS requires attending to the technology while addressing the critical care issues of the patient.

In respiratory failure, VV access is preferred. Gas exchange across the native lungs is usually minimal during the first several days of ECLS; therefore, the patient is totally dependent on the technology. As lung function returns, systemic blood oxygenation and CO\textsubscript{2} clearance improve, and the extracorporeal blood flow rate is gradually decreased, allowing the native lungs to assume a larger percentage of gas exchange. It is practical and safe to allow these patients to be awake and active, with extubation and ambulation as possibilities. When native lung function is sufficient, ECLS is weaned off and the patient is supported with non-damaging ventilator settings; cannulae are removed and recovery continues. Patients successfully weaned off ECLS have a 90% likelihood of complete recovery.

In cardiac failure, VA access is required. Arterial access is typically via the femoral artery, with distal limb perfusion assured by placing a small reperfusion line in the distal femoral artery or in the posterior tibial artery (46). Inotropes and pressors are weaned off, and systemic perfusion is maintained by extracorporeal flow. Lung function usually returns to normal in a day or two, and the patient can be awakened and extubated. When the patient is stable, and the function of other organs can be determined, a decision can be made about bridging to recovery or to ventricular assist device (VAD) and transplantation. When ECLS is used for cardiac support, the pulmonary and left ventricular blood flow is minimal; this can result in two problems. First, if the heart stops altogether, the left atrium and ventricle will gradually distend with bronchial venous blood, leading to high left atrial pressure and pulmonary edema. This is recognized by the lack of systemic arterial pulsatility. If this is the case, the left side of the heart must be decompressed, either by direct catheterization of the left atrium or by creation of an atrial septal defect. The second problem with VA bypass in the totally failing heart is thrombosis in the left atrium or left ventricle; this will occur even in the presence of systemic heparinization. Thrombosis is diagnosed by echocardiography; if a patient has left atrial or left ventricular thrombus, it is important to avoid spontaneous left ventricular function and the clot can be extracted at the time of VAD placement.

**CLINICAL RESULTS**

The most recent data from the ELSO registry are shown in Table 110.1. Participation in the ELSO is voluntary, but almost all cases treated with ECLS in established centers are included in the registry. There are currently over 65,000 patients listed in this Registry and the volume has doubled in the last decade. ECLS use in neonates has remained stable while the significant growth noted has been realized in pediatric and adult populations. Much data is collected, but the most important statistic is hospital discharge survival. ECLS is a life-support technique, applied only to patients with a high risk (80% to 100%) of dying who are not expected to survive with conventional treatment. The mortality risk is measured differently in different age groups.

**Neonatal Respiratory Failure**

The largest group of patients treated with ECLS is newborn infants with respiratory failure, of which there are only a few causes. ECLS survival for meconium aspiration, infant respiratory distress syndrome (IRDS), primary pulmonary hypertension of the newborn (PPHN), and neonatal sepsis is 80% to 95%, but only 60% for congenital diaphragmatic hernia. Excluding diaphragmatic hernias, these excellent results exist because respiratory failure in neonates does not destroy lung tissue. The pathophysiology is pulmonary hypertension with right-to-left shunting through the ductus arteriosus (persistent fetal circulation). During ECLS, the pulmonary vasculature relaxes, the ductus closes, and lung recovery occurs promptly. The problem in congenital diaphragmatic hernia is that the hernia compresses the lungs and causes bilateral lung hypoplasia in utero in addition to pulmonary vasospasm. The hypoplastic lungs may be too small to support the infant to recovery.

About 10% of surviving patients have some neurologic disability, with the most common being some degree of hearing loss. This is lower than the incidence of complications in critically ill infants not treated with ECLS, indicating that these are the complications of profound illness in the newborn. While the use of ECLS in neonatal respiratory failure has decreased since the introduction of nitric oxide, there are still approximately 1,000 new cases per year entered into the ELSO registry.

**Pediatric Respiratory Failure**

Severe respiratory failure in older children is relatively rare, compared to the incidence in newborn infants and adults, with the most common causes being viral or bacterial pneumonia.

### Table 110.1 Overall Patient Outcomes with ECLS for Cardiac and Respiratory Failure\(^\text{a}\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Total</th>
<th>Survival with ECLS</th>
<th>Survival to Discharge</th>
</tr>
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<tbody>
<tr>
<td>Neonatal</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Respiratory</td>
<td>27,728</td>
<td>23,358 (84%)</td>
<td>20,592 (74%)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5,810</td>
<td>3,600 (62%)</td>
<td>2,389 (41%)</td>
</tr>
<tr>
<td>ECPR</td>
<td>1,112</td>
<td>712 (64%)</td>
<td>449 (40%)</td>
</tr>
<tr>
<td>Pediatric</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>6,569</td>
<td>4,327 (66%)</td>
<td>3,760 (57%)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>7,314</td>
<td>4,825 (66%)</td>
<td>3,679 (50%)</td>
</tr>
<tr>
<td>ECPR</td>
<td>2,370</td>
<td>1,313 (55%)</td>
<td>976 (41%)</td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>7,008</td>
<td>4,587 (65%)</td>
<td>4,026 (57%)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>5,603</td>
<td>3,129 (56%)</td>
<td>2,294 (41%)</td>
</tr>
<tr>
<td>ECPR</td>
<td>1,657</td>
<td>639 (39%)</td>
<td>471 (28%)</td>
</tr>
<tr>
<td>Total</td>
<td>65,171</td>
<td>46,490 (71%)</td>
<td>38,636 (59%)</td>
</tr>
</tbody>
</table>

\(^{a}\)Extracorporeal Life Support Organization registry data, January 2015. The data for 2014 are incomplete. ECLS, extracorporeal life support; ECPR, extracorporeal cardiopulmonary resuscitation.
Survival rate approximates 66%, varying based on the primary condition. The effectiveness of ECLS in pediatric respiratory failure was demonstrated in a contemporary matched-pairs study by Green et al. (47). Most children with respiratory failure can be managed successfully with VV access. The most common cause of death is progressive lung destruction from the primary infection, or brain damage from the period of hypoxia and ischemia that preceded ECLS. These children are all essentially normal in follow-up. Once the lung recovers, pulmonary function and exercise tolerance return to normal.

**Adult Respiratory Failure**

The cause of ARDS is a primary lung event in about half the cases (viral or bacterial pneumonia, aspiration, pulmonary vasculitis, etc.), and secondary to extrapulmonary causes in the others (shock, trauma, pancreatitis, sepsis). The overall mortality for ARDS approximates 30%, even with excellent management. ECLS is indicated for those patients who have a high mortality risk within the first week after intubation. These patients are relatively easy to identify; they have an alveolar–arterial (A-a) gradient for oxygen greater than 600 on day 2, 3, or 4 following initial intubation. The mortality risk for those patients is approximately 80%, and the recovery rate with ECLS in these same patients approximates 70% (48–51). Patients on the ventilator more than 5 days pre-ECLS have a lesser chance of recovery; hence the overall survival rate for ECLS treatment of ARDS is approximately 57%. The University of Michigan has reported the largest experience with ECLS for ARDS; in that series, the overall survival rate was 52% (48). More recently, they reported their experience with 2,000 ECLS patients, of which 353 were adult respiratory patients, with survival to discharge of 50% (52). These series are large enough to characterize the patient population and identify the likelihood of recovery based on age and days on mechanical ventilation.

Adult respiratory ECLS requires VV bypass, with high blood flow adequate to sustain oxygenation and CO₂ removal. Lung rest, diuresis, and prone positioning have led to the 50% to 60% survival, discussed above. The dual lumen cannulae make single-site cannulation possible for VV bypass. The cannulae are designed to be placed in the right internal jugular vein, using fluoroscopy to confirm safe placement. It is practical to minimize sedation, extubate and help patients out of bed so they can ambulate and participate in physical therapy (53,54). Severe ARDS treated without ECLS requires uncomfortable modes of ventilation. With this discomfort comes the dependency on heavy sedation or even paralytics. The critical care literature has well-described survival and quality-of-life risks related to sedation (55–57) and these risks can be minimized with ECLS.

**Cardiac Failure in Children**

VA ECLS is currently the only mechanical support system available for children in the United States. Most of the children treated with ECLS have cardiac failure following a cardiac operative intervention, usually for congenital heart disease. These patients cannot be weaned from cardiopulmonary bypass in the operating room, or are weaned but remain in profound cardiac failure despite full inotropic support following surgical intervention. Patients who cannot be weaned from cardiopulmonary bypass in the operating room, or are weaned but remain in cardiac failure have cardiac failure following a cardiac operation. Vascular access is usually achieved by cannulation of the right atrium via the right internal jugular or femoral vein, with arterial return retrograde via the femoral artery. Intra-aortic balloon pumping is possible in adults and will support approximately 40% of the cardiac output. Most patients treated with ECLS have failed balloon pumping, as well as full inotropic support. If a balloon pump is in place through one of the femoral arteries, it is best left in place because of the risk of bleeding once the device has been removed. The opposite femoral artery is used for arterial access; distal limb perfusion is assured as previously described.

Adult patients in acute cardiac failure are candidates for left ventricular assist device (LVAD) placement as a bridge to recovery or a bridge to transplantation. However, in the acute failure situation it is best to institute ECLS first, stabilize the circulation and gas exchange, and determine if other organs are functioning, most importantly the brain. If severe brain injury has occurred, ECLS is discontinued, avoiding the futile and expensive LVAD placement. The survival for ECLS in adult cardiac failure is 40% to 50% (59–62).

**Cardiac Failure in Adults**

The experience with ECLS for cardiac failure in adults is shown in Table 110.1. The most common indication for ECLS for cardiac support in adults is acute myocardial failure following myocardial infarction or heart failure following cardiac operation. Vascular access is usually achieved by cannulation of the right atrium via the right internal jugular or femoral vein, with arterial return retrograde via the femoral artery. Intra-aortic balloon pumping is possible in adults and will support approximately 40% of the cardiac output. Most patients treated with ECLS have failed balloon pumping, as well as full inotropic support. If a balloon pump is in place through one of the femoral arteries, it is best left in place because of the risk of bleeding once the device has been removed. The opposite femoral artery is used for arterial access; distal limb perfusion is assured as previously described.

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EXTRACORPOREAL LIFE SUPPORT FOR CARDIOPULMONARY RESUSCITATION

ECLS can be used in association with resuscitation to support cardiac and pulmonary function in cardiac arrest or profound shock. In this application, the ECLS circuit must be primed and available within minutes. Therefore, ECLS for cardiopulmonary resuscitation (ECPR) cases are done primarily in established ECLS centers, which have both the equipment and the team to institute ECLS on a moment’s notice. The limiting factor in establishing ECLS in these cases is vascular access. It is difficult to get rapid arterial and venous access in a patient in full cardiac arrest. Most successful ECPR cases have been in patients who arrested, then briefly resuscitated, with simple vascular access gained following initial resuscitation. Then, ECLS cannulae can be placed over a wire through smaller catheters if, and when, the patient arrests again or proceeds to cardiogenic shock or intractable dysrhythmias. In our institution, we consider ECPR for patients who have been in cardiac arrest for less than 5 minutes. A few patients who have been arrested with full and well-documented resuscitation for over an hour have been treated successfully, but if the arrest has been prolonged, and if profound metabolic acidosis exists, then establishing ECLS is often futile. The overall results for successful, healthy survival after ECPR is approximately 40%, much better than the 5% successful results of external message only (63–67).

OTHER APPLICATIONS OF ECLS

The ability to totally control perfusion and gas exchange with an extracorporeal system offers unique opportunities in other aspects of acute medical care. Profound hypothermia can be treated by extracorporeal support; this is particularly important because patients who are hypothermic may develop ventricular fibrillation during external warming. Hypothermia associated with exsanguinating hemorrhage in the operating room can be treated successfully with ECLS. Perfusion is maintained during the period of bleeding, and hypothermia can be maintained to protect organ function. After bleeding is controlled, blood is returned to the patient associated with warming to avoid the coagulopathy caused by low temperature. Hyperthermic perfusion can be established, either for total body warming or for regional warming, as an adjunct to cancer chemotherapy.

ECLS can be used to specifically resolve hypercarbia, requiring flows equivalent to about 10% to 20% of the cardiac output. This is being used to support hypercarbic COPD patients and patients with status asthmaticus (68–70). Septic shock was once considered a contraindication to ECLS. However, sepsis often clears during ECLS, and this has become a standard indication in our institution. It is common for patients in septic shock to regain normal vascular tone and to come off all vasopressors within a day or two of instituting ECLS (71). This is partly related to establishing healthy perfusion and gas exchange, and partly related to adsorption of inflammatory mediators by the plastic in the circuit.

ECLS has also been used to support perfusion in potential organ donors, particularly in situations in which death prior to organ donation occurs because of cardiac arrest following elective withdrawal of ventilator support (72).

SUMMARY

A decade ago, you might have turned to this chapter as a last resort for a patient dying in your ICU. You would have likely been an intensivist doing your best with unconventional ventilation modes, an oscillator or NO; ECLS was not available in your hospital. Today, you may be a pulmonologist who has been learning about ECMO at your national meetings. Perhaps you are an ED physician just returning from an ELSO Course on Adult ECMO and you are interested to learn more. Maybe you are a cardiothoracic surgeon who has been asked to help start an ECMO program by your ICU or ED. Maybe you are a hospital administrator charged with understanding the finances related to ECLS. ECLS has evolved in the past 10 years because of modern affordable technology and evidence that ECLS is cost effective and life sustaining. Patients are walking the critical care unit while on ECLS. Unheard of when the previous edition was written.

ECLS sustains cardiac and pulmonary function by mechanical means for patients with profound cardiac or respiratory failure. The technology includes extracorporeal vascular access, perfusion devices, and management of anticoagulation. ECLS does not treat cardiac or pulmonary failure, but offers hours or days of time to establish a diagnosis and allow time for organ recovery or replacement. Overall success is measured as survival because ECLS is used only in patients at a high risk of dying from acute heart or lung failure. Healthy survival ranges from 95% in some cases of newborn respiratory failure to 40% when ECLS is used as adjunct to cardiac resuscitation.

Key Points

- ECMO (ECLS) provides cardiopulmonary support in severe heart or lung failure.
- For support of circulation, ECLS is used in the VA mode. For respiratory failure, ECLS is used in the VV mode.
- The extracorporeal circuit includes a blood pump, membrane oxygenator, and heat exchanger.
- During ECLS, blood is anticoagulated with continuous infusion of heparin or a direct thrombin inhibitor.
- The major risk is clotting in the circuit or bleeding in the patient.
- The success (healthy hospital discharge) rate is 50% for cardiac support, 65% for respiratory support.

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