Extracorporeal circulation in 2050: a speculation

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Case scenario

In 2050, a 60-year-old (middle-aged) man has a large myocardial infarction. As he collapses, he vomits and aspirates gastric contents. He has two episodes of ventricular fibrillation, but is successfully defibrillated by his wife. Twelve hours later, he is in the 200-bed intensive care hospital (all inpatient beds are intensive care beds). He is fluid overloaded, in pulmonary edema and cardiogenic shock, and has no urine output. The team from the regional advanced critical care center is called. They arrive, cannulate the patient for venoarterial extracorporeal circulation. No anticoagulants are used. The circuit includes a filter that is used for continuous hemodiafiltration and nutrition and administration of all of his drugs. On the extracorporeal circulation, he is transported to the advanced critical care center, where he has a coronary revascularization by the interventional radiologist and placement of a left atrial drainage catheter; however, his myocardial function does not improve and his acute respiratory distress syndrome (ARDS) is worsening. As plans are made for an implantable assist device and later heart transplant, his pneumonia progresses to septic shock, so a sepsis cartridge is inserted into the circuit with prompt resolution of his symptoms.

Overview

This will be a typical use of extracorporeal circulation 50 years from now. Vascular disease, respiratory failure, renal failure, and infection will still be the final common pathways of mankind. Temporary and permanent mechanical devices to treat these problems will be commonplace. The applications of extracorporeal circulation and the technical details of that technology are discussed in this speculation.

Operating room – applications of extracorporeal circulation

Operations on the heart continue to be a major application of extracorporeal circulation, which will include routine placement, replacement, and removal of mechanical cardiac support devices and cardiac transplants. Cardiac transplantation, like all solid organ transplantation, will be commonplace and facilitated by organ banks in which human organs are maintained for months using techniques adapted from extracorporeal circulation. Organ perfusion technology will be used, not only for preserving and banking organs for transplantation and other purposes, but will include routine isolated organ perfusion in the operating room.

With the advent of completely nonthrombogenic extracorporeal circuits, it will be common to use extracorporeal circulation for any major operation, with individual organ perfusion lines for aortic operations, other vascular operations, transplant, implant, and reimplant operations, and regional chemo- and antiseptic therapy. The routine use of extracorporeal circulation in all operating rooms will allow profound hypothermia and low-flow cardiac arrest to permit easy access to difficult areas for neurosurgical procedures.

The same technology will allow prolonged hypothermic perfusion for exsanguinating hemorrhage from injuries, vascular rupture, and trauma while the organ and vessels are repaired. In those cases,
and in other cases involving major bleeding and cardiogenic shock in the operating room, extracorporeal circulation will be used for control of the circulation, resuscitation, temperature control, and support until native or mechanical organs can replace damaged or diseased organs.

**Extracorporeal circulation applications in critical care**

Extracorporeal circulation with extrathoracic access will be used routinely for acute cardiac failure and cardiogenic shock leading to recovery or cardiac replacement. The same technology will be used for acute respiratory failure leading to recovery or prosthetic lung replacement bridging until transplantation. Unlike 50 years before, when prolonged extracorporeal circulation with a roller pump and spiral-coil membrane oxygenator (then called ECMO) was used simply to allow time for native organs to heal, in 2050, damaged lungs will be filled with fluorocarbon loaded with antibiotics, antiseptics, and growth factors, resulting in prompt healing of the damaged lungs. Similar active treatment will be used for the acutely failing heart, kidney, and liver.

Acute renal and liver failure will be managed by extracorporeal blood treatment techniques, combining continuous plasma separation and processing of the plasma by sorbent cartridges to maintain normal homeostasis. This technology of extracorporeal blood treatment will be widely used to allow removal or modification of specific molecules or cells in the blood for treatment of sepsis, hematologic malignancies, antigen antibody reactions, and toxic conditions. Extracorporeal circulation in the intensive care unit will be the routine and first-line treatment of septic shock, exsanguinating hemorrhage, and resuscitation from anaphylaxis or cardiac arrest. Transportation of critically ill patients on extracorporeal circulation will be routine.

**Extracorporeal circulation technology**

Human anatomy will be unchanged 50 years from now, so that extrathoracic vascular access for extracorporeal circulation will be via the jugular veins in the neck, the femoral veins in the groins, the femoral arteries and carotid arteries. Periodically, attempts to use the subclavian or axillary artery will be attempted, but limited by distal perfusion of the hand and arm. Vascular access catheters will be placed with the aid of a probing needle with ultrasound imaging guiding the needle directly to the vessel followed by Seldinger’s spring wire placement. A single device will be threaded over the spring wire under ultrasonic guidance to assure its proper position. This device will begin with a long, narrow, flexible tip leading to an obturator and ending in an appropriately sized vascular catheter. Paramedics and nurses will routinely place vascular access catheters.

Two types of pump will be in use: small, high revolutions per minute axial flow pumps developed around the turn of the century (safe and suitable for 24-hour application, but expensive), and peristaltic pumps with a passively filling chamber (safe, fairly large and inexpensive). Prosthetic membrane lungs with passively induced secondary flows will be used routinely. All the prosthetic surfaces will slowly leach short-acting platelet inhibitors such as nitric oxide, and fibrin-inhibiting agents that act on factors X-a and IX-a, preventing fibrin formation. Both the external and internal surfaces of intravascular devices will be coated, eliminating the need for any systemic anti-coagulation. Platelet transfusion will be unnecessary, particularly with the use of thrombopoietin, which is routinely available. Circuits for both the operating room and the intensive care unit will be entirely closed and non-compliant systems without large reservoirs or filters.

Additionally, the cardiopulmonary bypass system used in the operating room will be totally automated with blood flow, gas flow, and safety features servo-regulated by inline sensors of blood gas composition and patient sensors of oxygen consumption, oxygen delivery, and effective blood volume. The extracorporeal circuit will have a modular design, with convenient attachment of extracorporeal blood treatment devices to permit hemodiafiltration, plasma separation, and plasma processing, treatment of sepsis, temperature control, and selective adsorption of undesirable molecules in renal failure, liver failure and other toxicities.

Fresh, whole, sterile, risk-free blood will be available without limit because it is produced by the Red Cross by organ banks of seeded simulated marrow and hepatocytes growing in bioreactors, all stimulated by genetically engineered erythropoietin, thrombopoietin, granulocyte-stimulating factor, liver trophic hormones, and other growth factors. Because of the unlimited availability of blood and plasma products, the use of crystalloid fluid treatment and resuscitation, so widely practiced before the turn of the century, will have long disappeared in favor of using blood or plasma to maintain normal fluid, electrolyte, and blood volume homeostasis.
**Major advances between 2000 and 2050**

In closing, although the applications and technology described above will happen in small increments, the major steps in the growth and application of extracorporeal circulation will be: 1) development of nonthrombogenic materials; 2) simplified and routinely reliable vascular access devices; 3) routine extracorporeal blood treatment to manage renal, liver, and host-defense failure; 4) total automation of extracorporeal systems, eliminating the need for continuous attention; and 5) prolonged organ preservation allowing organ banks and blood factories.