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# Technological Innovations in Intensive Care Unit

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### Abstract

Intensive care units (ICUs) are equipped with advanced technology within the hospital and are specially structured, providing 24-hour support every day of the week. These units have health personnel experienced in the monitoring of severe illnesses. As a result of developments in science and technology, the techniques used in ICUs have also improved.

**Keywords:** Intensive care, technology, cerebral oximetry

## INTENSIVE CARE UNIT AND TECHNOLOGICAL INNOVATIONS

Intensive care units are special units in which patients are closely monitored and treated due to a life-threatening critical disease. Respiratory failure, severe infections, heart attack, sudden cardiac arrhythmias, coma, shock, serious trauma and accidents, intoxications, and post-operative special conditions requiring a close follow-up are the most common reasons for hospitalization in the ICUs.

Intensive care units are specially structured units equipped with advanced technology within the hospital, which provides 24-hour support every day of the week. In these units, health personnel experienced in the monitoring of severe diseases are assigned (1). As a result of developments in science and technology, the techniques used in ICUs have also improved.

**TELE-ICU:** It stands for the remote management of ICUs. Efficient decisions can be made from a high-tech command center by connecting to the ICUs through audio-visual/video conferencing and monitoring. All patient data are reflected to the monitors in real time by means of intensive care automation, which provides 24/7 data monitoring and are then recorded (Figure 1). Furthermore,

- It shortens the duration of stay in the intensive care.
- It contributes to the reduction of mortality rates.
- It increases the bed usage cycle in ICUs.
- It helps to minimize medication errors and other medical errors.
- It provides economic efficiency. (2)

**Mixed Venous or Central Venous Oxygen Saturation ($SvO_2$/$ScvO_2$)**: It is the parameter that reflects the balance between the arterial oxygen delivery and oxygen usage of tissues. Considering the formula $DO_2$=CO×$CaO_2$ ($DO_2$, oxygen delivery to the tissue; CO, cardiac output; $CaO_2$, oxygen content of arterial blood), the difference between the amounts of venous and arterial oxygen can only be taken as the difference between oxygen saturations when unchanging variables such as fixed numbers and hemoglobin in the two systems are removed from the equation.

In this case, the cardiac output is directly related to the difference in venous and arterial oxygen saturation. The normal range of mixed venous saturation is 65%-70%. Mixed venous saturation decreases when the oxygen delivery decreases or oxygen consumption of the tissue increases. Again, when the cardiac output is reduced or circulation impaired, a decrease is observed in mixed venous saturation because the oxygen extraction will increase. The monitoring of mixed venous oxygen saturation allows early detection of tissue hypoxia, and it is important. In patients

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with circulatory and cardiac problems, mixed venous saturation monitoring is particularly important in the titration of inotropic therapy. Although there are catheters that can perform continuous monitoring of mixed venous saturation, they are not widely used. Mixed saturation monitoring is performed with intermittent blood gases in most centers (3).

**Pulse Index Contour Continuous Cardiac Output (PICCO):** This is a device that can continuously measure the cardiac output through the femoral artery with the pulse contour method, without any need for pulmonary artery intervention. The measurement process starts with the standard Stewart-Hamilton thermodilution technique, and it allows continuous cardiac output to be monitored by pulse contour analysis over the artery trace. In addition, it also measures the values of the intra-thoracic blood volume and extra-vascular lung water and provides an idea on cardiac pre-load and lung fluid. Therefore, it is particularly useful for monitoring the fluid balance (volume management) of patients under the mechanical ventilation support. PICCO with a central venous catheter and a femoral artery is an advanced hemodynamic monitor used to follow up patients with cardiac problems (Figure 2) (4).

Figure 1. TELE-ICU

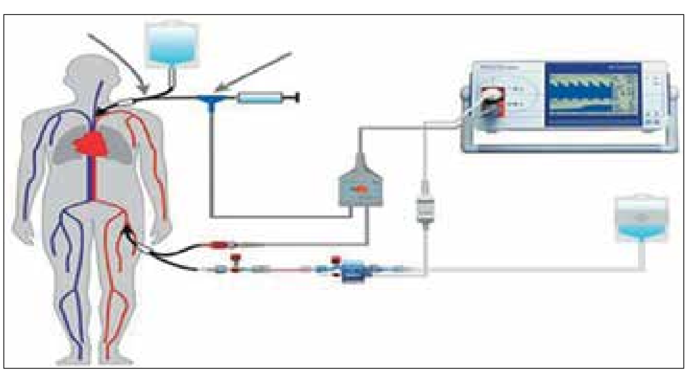

Figure 2. PICCO-Plus System (The permission of PULSION Medical Systems SE.)

**Echocardiography**: After the widespread use of ultrasonography in ICUs, the application of echocardiography by intensive caregivers without a cardiologist has also become widespread. Moreover, the guidelines for this examination, which can be called cardiac ultrasonography, have been published. The parameters evaluated in this examination are the inferior vena cava diameter, prediction of preload from the right and left ventricle end-diastolic diameters, right ventricular/left ventricular functions, regional wall motion abnormalities, pericardial effusion and tamponade, and valvular structure status (5).

**Lactate Measurement**: It is the intermediate metabolite pyruvate occurring due to glycolysis in the cytoplasm, and it is converted into lactic acid under anaerobic conditions. There are two types of lactic acidosis.

Type A: There is a decrease in tissue perfusion or oxygenation. Lactate production increases due to tissue hypoxia in circulatory and respiratory failure or diseases impairing the Hb-oxygen transport.

Figure 3. MeasurementTranscutaneous of $CO_2$

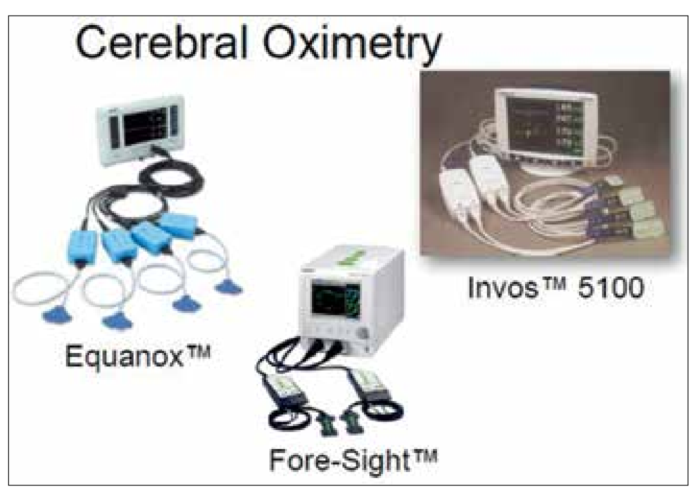


Figure 4. Near-infrared spectroscopy

Type B: The main cause is not tissue hypoxia, and the use of oxygen by the tissues is impaired due to a primary cause. Liver diseases, thiamine deficiency, gluconeogenesis, or factors impairing oxidative phosphorylation cause a decrease in the lactate utilization.

Since an increased lactate level is significant in diagnosing, demonstrating hypoxia and hypoperfusion, or predicting early mortality, lactate measurement with blood gas devices is highly valuable.

**Transcutaneous $CO_2$ Measurement:** It is performed with a small electrode placed on the skin. The heating wire inside the electrode increases the permeability of the epidermis and increases the gas diffusion through the capillary. Although it is a practical method, it should be confirmed by the arterial blood gas or $ETCO_2$ if the patient is intubated because conditions such as hypothermia, hemodilution, and low arterial blood pressure affect the optimum measurement conditions of the device, such as an access to the appropriate temperature, high capillary perfusion, and calibration (Figure 3) (6).

**Near-Infrared Spectroscopy (NIRS):** NIRS is a technique measuring the amount of absorption caused by chromophore molecules-such as oxyhemoglobin ($O_2Hb$) and deoxyhemoglobin (HHb), cytochrome-c oxidase (CCO), and myoglobin-while the near-infrared light is passing through the tissues (7). The measurement of $O_2Hb$ and HHb concentration changes in tissues by The NIRS technique was first performed by Jöbsis et al. in 1977. It was guiding the measurement of tissue oxygenation, and NIRS was begun to be used to evaluate the oxygen status of the brain tissue (8). Cerebral oximetry is the name of the method in which the regional cerebral oxygen saturation values are measured noninvasively and continuously using the NIRS technique (Figure 4) (9).

**BIS Monitoring:** As is known, sedation is very important in ICUs. It is necessary to adapt the patients to mechanical ventilator treatment and to achieve the optimal level of sedation for their hemodynamic stabilization. Inadequate sedation and sudden changes in consciousness disturb the patient's comfort and may lead to negative consequences such as inadequate ventilation,


Figure 5. BIS-VISTA Monitoring system


Figure 6. BIS Complete 2 Channel Monitor-Covidien

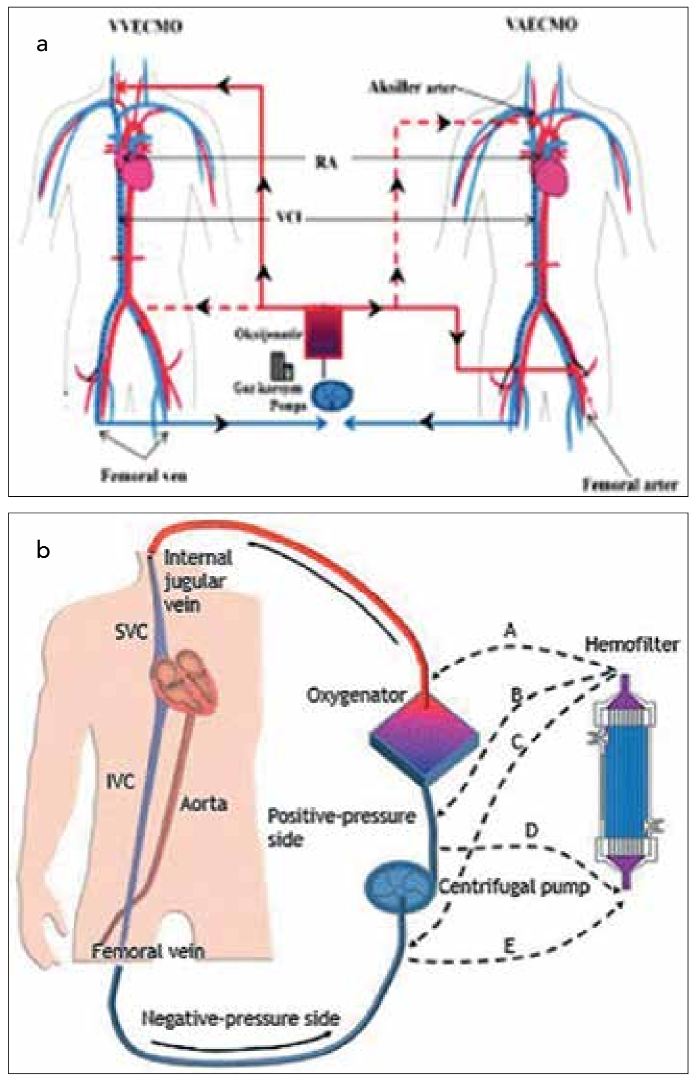


Figure 7. a, b. Extracorporeal Membrane Oxygenation (ECMO). (a) Veno-venous Extracorporeal Membrane Oxygenation (b) Veno-arterial Extracorporeal Membrane Oxygenation

hypertension, and tachycardia. On the other hand, excessive sedation may adversely affect the cardiovascular functions and lead to a prolonged mechanical ventilation. Moreover, it increases the risk of developing physical dependence and tolerance. For these reasons, the sedation dose should be regularly adjusted with continuous monitoring of the patient's sedation level (10). BIS is an EEG parameter. BIS monitoring is used to measure changes in the consciousness of sedated patients in a continuous, objective, and reliable way. The BIS index is a number ranging from 0 to 100, and it is correlated with significant clinical conditions during an anesthetic agent administration. While BIS values around 100 indicate that the patient is awake, the value of 0 indicates an isoelectric EEG. In prospective studies, it has been reported that keeping the BIS index values between 40 and 60 during the stay in the ICU provides an adequate hypnotic effect (Figure 5, 6) (11).

Figure 8. Mechanical ventilator devices

Figure 9. Hemodiafiltration device

**Extracorporeal Membrane Oxygenation (ECMO)**: ECMO is the process of a temporary support of respiratory and/or cardiac functions in patients who do not respond to conventional therapy. Blood taken from the patient with an external pump through cannulas and placed in the large vessels is passed through the membrane (oxygenator), and gas exchange is provided. It is then given to the patient again. It is usually applied in two ways for pulmonary (veno-venous) and cardiopulmonary (veno-arterial) support (12).

**a) Veno-venous Extracorporeal Membrane Oxygenation:** VV-ECMO is the most common technique in patients without severe cardiac dysfunction, but with isolated respiratory failure, severe ARDS, and refractory hypoxemia or hypercapnia. Its purpose is to provide oxygenation, to rest the lungs, and to reduce the damage caused by mechanical ventilation.

**b) Veno-arterial Extracorporeal Membrane Oxygenation:** VA-ECMO can be used for both the left and right ventricular failure. For the return of oxygenated blood, the cannulation of the ascending aorta or femoral artery is required. By bypassing these, VA-ECMO reduces the pulmonary artery pressure, increases systemic perfusion, and provides higher PaO2 levels compared to VV-ECMO. VA-ECMO functions parallel to the heart and lungs (Figure 7. a, b.) (13). While the advantages of ECMO are in pro-


Figure 10. Critocool-pro

viding the support to both the heart and lungs, enabling the arterial and venous cannulation from a single site, providing good oxygenation even at low flow, and being independent of cardiac functions, its disadvantages include the risk of embolization due to thrombi particles present in the system, the requirement of carotid ligation, a possible transfer of hyperoxygenated blood flow to the brain, and bleeding with coagulopathy.

**Mechanical Ventilator Devices:** Ventilators are devices that enable breathing by sending the gas flow to the patient's airways in a controlled manner when spontaneous respiration required to sustain life is threatened. Unlike old machines, which in the simplest way only provide mandatory breathing to the patient, new ventilator devices offer many mode options that can adjust each stage of the breathing. The options such as continuous mandatory ventilation; assist control; synchronous intermittent mandatory ventilation; continuous positive airway pressure ventilation; volume-controlled ventilation; pressure-supported ventilation, pressure-controlled ventilation; and very new modes including volume-assured pressure support, volume-supported, pressure-regulated volume control, proportional assist ventilation, and bilevel positive airway pressure ventilation allow us to select the ventilation type specific to each patient group. While only $fiO_2$, the tidal volume, number of breaths, and pressure settings can be adjusted on the old machines, the settings of PEEP, triggering, the inspiratory/expiratory ratio, flow rate, inspiration time, expiration time, and the peak inspiratory pressure can be adjusted at present (Figure 8). Noninvasive mechanical ventilation (NIV) is a preferred method of ventilation in appropriate patients due to the reasons such as avoiding complications of endotracheal intubation, preventing nosocomial infection and ventilator-related infections, reducing the need for sedation, and reducing the hospital stay. In the past, separate devices were required for this method; however, it is possible to perform NIV with new modes added to the mechanical ventilators used in ICUs in recent days. Since the mask is used during NIV, there is almost always air leakage. However, in these new machines, leak compensation is sensitive, and sufficient and ventilation support tolerates leakage. Although conventional NIV machines have a single tube, intensive care ventilators have double tubes, which prevents carbon dioxide retention, which is very important for NIV patients (14-18).

**Hemodiafiltration:** Renal insufficiency requiring renal replacement therapy is a commonly encountered condition in intensive care patients. Compared to conventional intermittent hemodialysis, continuous renal replacement therapy (CRRT) has the advantages of less disturbance to hemodynamic stability, a better control of the intravascular volume, and less electrolyte acid-base disturbances. CRRT develops in parallel with the development of technology in this field. Thanks to the development of pumps and sets, it has become possible to carry out a longer and more effective procedure. CRRT is named according to the type of vascular intervention and whether diffusion or convection is used. Although the CRRT techniques can be divided into arterio-venous and veno-venous techniques according to the catheter entry site, no arterio-venous method is used anymore (Figure 9) (19-21).

**Hypothermia:** In patients with appropriate indications, after providing spontaneous circulation following cardiopulmonary resuscitation, the body temperature is reduced to 32-34°C within the first 4-6 hours to obtain a successful neurological return, and after the target temperature is reached, it is kept stable at this level for 12-24 hours (18 hours on average). This process is called therapeutic hypothermia.

By inserting a special balloon catheter from the femoral or jugular vein, continuous cold water is pumped for circulation through a special hypothermia device from the balloons on the catheter, and it is aimed to reduce the body temperature by cooling the circulating blood. After reaching the target temperature, the heating process is started after 18 hours on average (12-24 hours). Heating is a slow process in contrast to the induction phase. With the help of the device, the heating is done in an average of 6 hours with a temperature of <0.5°C increased per hour. This slow heating process prevents imbalances that may occur in hemodynamics, metabolism, and electrolyte values (22).

It is accepted that the early initiation of therapeutic hypothermia in selected patients after cardiac arrest prevents the chemical reactions caused by reperfusion injury, contributes to the neurological recovery, and may hinder the progression of damage. It is important that the cooling process is initiated as early as possible after patient responding to resuscitation and that the patient is kept at an appropriate temperature, which is performed with the latest hypothermia devices (Figure 10) (23, 24).

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