

# A Guide for International Students to Intraoperative Monitoring in General Anesthesia

Iita Niutanen

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JYVÄSKYLÄN AMMATTIKORKEAKOULU  
JAMK UNIVERSITY OF APPLIED SCIENCES



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Abstract  <p>The objective of the thesis was to increase nursing students' understanding of intraoperative care and anesthesia. In addition, the aim was to facilitate the work of the nursing students' mentors. The theoretical base of the thesis is intraoperative nursing and anesthesiology.</p> <p>Universities of applied sciences place great emphasis on practical training in the nursing programme's curriculum. The end-result of this thesis is a guide on intraoperative monitoring in general anesthesia for international students. It entails the principles of monitoring a patient under general anesthesia and different variables affecting it. To promote learning in practice the guide was designed to be used as a learning tool. It is directed towards building up the student's intraoperative monitoring knowledge and skills. The guide is also suitable for the use of nurse mentors to use when giving job orientation or instruction to students. The project was assigned by the Central Finland Central Hospital and students in anesthesia practice can download the guide from the hospital's intra web.</p>		
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Tiivistelmä  Opinnäytetyön tavoitteena oli lisätä sairaanhoitajaopiskelijoiden ymmärrystä intraoperatiivisesta hoidosta ja anestesiasta. Tämän lisäksi pyrkimys oli helpottaa opiskelijaohjaajien työtä leikkausosastolla. Opinnäytetyön teoreettinen perusta on intraoperatiivisessa sairaanhoidossa ja anestesiologiassa.  Ammattikorkeakoulut painottavat hoitotyön opintosuunnitelmassa käytännön harjoittelua. Tämän opinnäytetyön tuloksena syntyi opas yleisanestesian aikaisesta potilasvalvonnasta kansainvälisille opiskelijoille. Teoksessa määritellään potilasmonitoroinnin perusteet yleisanestesian aikana sekä erinäisiä monitorointiin vaikuttavia tekijöitä. Opas on suunniteltu oppimistyökaluksi ja tukee harjoittelussa oppimista. Oppaan tarkoituksena on opiskelijan tietojen ja taitojen kehittäminen intraoperatiivisessa monitoroinnissa. Tämän lisäksi opas on tehty soveltuvaksi opiskelijaohjaajien työhön opiskelijoiden perehdytykseen ja ohjaukseenkin. Projekti on tuotettu Keski-Suomen Keskussairaallalle ja opas on harjoittelussa olevien opiskelijoiden ladattavissa sairaalan omasta intranetistä.		
Avainsanat (asiasanat) Anestesia, intraoperatiivinen, sairaanhoito, monitorointi, opas		
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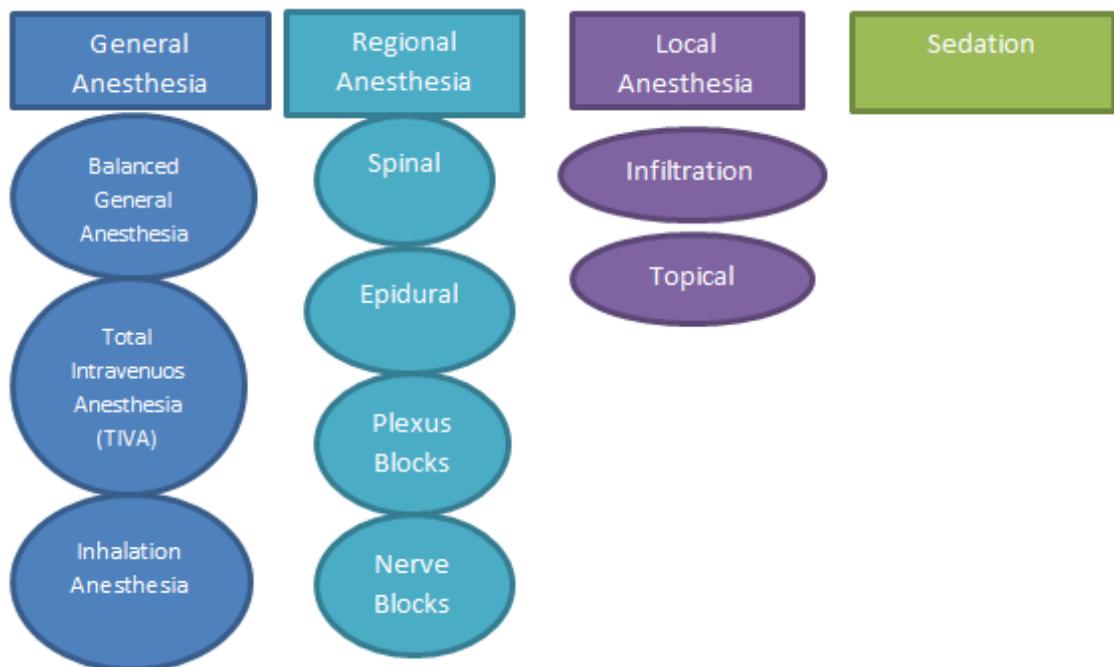
## 1 Introduction

Everyone working in the intraoperative setting should know the principles of patient monitoring. This is to ensure patient safety and avoid doing harm to the patient. Technical innovations have enabled more varied and accurate patient monitoring in anesthesia in recent years. We have an increased number of monitors giving us more detailed information on the physiology of an anesthetized patient. However, the risks of misinformation, misinterpretation, and compromised patient safety have increased correspondingly. Thus, in addition to knowing how the machines are operated, there needs to be an understanding of the limitations of monitoring devices. (Aitkenhead, Smith & Rowbotham 2007, 345, 361.) A trained and experienced health care professional is always the best patient monitor. He acts as the interpreter and facilitator between the monitoring machines and the patient.

This is a work-development related thesis produced as a project to Central Finland Central Hospital. The theoretical base of the thesis is on intraoperative nursing and anesthesiology. The end-result of the thesis is a guide for international students to intraoperative monitoring in general anesthesia. The guide is applicable for self-learning, student orientation, and can be used a learning tool between students and mentors.

Anesthesia is a pharmacologically induced reversible state during which surgical procedures can be done to patient (Virtanen 2007). Types of anesthesia (Figure 1) can be categorized into general anesthesia, regional anesthesia, local anesthesia, and sedation. These can also be combined to achieve a desired effect, emphasize a certain effect or minimize unwanted side effects. The choice of anesthesia type depends on several factors such as the length of surgery, the operated area, patient's age and general health, and demands of the situation. (Tunturi 2013.) This thesis concentrates on general anesthesia the components of which are sleep, lack of pain (analgesia), amnesia (no memory of from anesthesia), and sufficient muscle relaxation. This is achieved by administering anesthetic agents intravenously and/or anesthesia gases via mask. (Virtanen 2007.) Unobstructed airway is

secured with intubation tube or laryngeal mask through which the oxygen and anesthesia gases pass into and out of the patient with the help of anesthesia machine. Anesthesiologist decides the anesthesia method, induces anesthesia and terminates it. She is responsible for the patient's vital functions during surgery and orders administered drugs. Anesthesiologist is assisted by nurse anesthetist. (Lukkari, Kinnunen & Korte 2007, 303-305.) Good anesthesia is conducted safely, ensures painlessness for the patient also post-operatively, and is quick to recover from (Virtanen 2007).



**FIGURE 1 Types of Anesthesia**

Intraoperative phase begins at patient admission to the operating theater. The patient is prepared for operation, anesthetized, monitored, and surgical operation is performed. (Spry 2009, 2.) Intraoperative care is systematic and well-planned team work. A team of doctors, surgeons, and nurses work in co-operation for the benefit of the patient's welfare. (Iivanainen, Jauhiainen & Syväoja 2012, 479-481.) Intraoperative nursing activities center on facilitating the procedure, promoting patient safety, preventing infection, and monitoring and aiding the patient's physiological wellbeing. The intraoperative phase lasts until transferal to post anesthesia unit. (Op cit 2009, 2.)

In Finland, nurse anesthetist is a registered health care professional who works in the perioperative setting. Nurse anesthetist operates in the Operating Room (OR), Post Anesthesia Care Unit (PACU), and in out chapters where anesthesia is required such as in radiology, magnetic resonance imaging, endoscopies, and electroconvulsive therapy. (Poikajärvi & Immonen 2010.). During the entire perioperative phase the nurse anesthetist is responsible for ensuring her patient's holistic well-being and safety. The nurse anesthetist works in close co-operation with anesthesiologist. Together they form a team that administers, maintains, and ends anesthesia. Prior to operations, nurse anesthetist reserves and prepares the equipment needed. She must know how to operate the machines required in anesthesia monitoring and check their functioning. As a preparation the nurse anesthetist collects patient data such as laboratory results and evaluates its relevance to anesthesia. (Suomen Anestesiahoitajat ry.) During the intraoperative phase the nurse anesthetist is responsible for pharmacologic care, patient monitoring, and supporting vital functions. Her actions are in accordance with the anesthesiologist's care plan. (Rättö 2010.) Administering and planning fluid therapy is one of the nurse anesthetists' duties. She has to have the knowledge and skills to perform blood transfusion therapy and conduct invasive monitoring. In addition, ability to know how to act in an emergency and resuscitate correctly is required. (Tengvall 2011.) In regional and local anesthesia where the patient is awake the nurse knows how to give information and guidance (Iivanainen et al 2012, 482). It is a skill for the nurse to know how and when to give emotional support. When the patient is transferred to PACU or other care units the nurse anesthetist gives a report to ensure the continuity of the care. In the PACU nurse anesthetist monitors patients and gives post-operative care until the patients' condition allows transferal. The nurse is familiar with different methods of pain management and is able to carry out them. In day surgery units, nurse anesthetist gives post-operative care guidance and discharges patients. In all of the perioperative phases nurse anesthetist documents the performed interventions to the patient and other relevant issues. (Rättö 2010.) In her responsible work, the nurse anesthetist has to possess an extensive physiological and pharmacologic knowledge base to be proficient (Tengvall

2011). Her actions should always be juridical and follow the ethical principles of nursing (Suomen Anestesiahoitajat ry).

## **2 Patient monitoring in general anesthesia**

Anesthesia and surgery impact the patient's physical functioning and predispose it to a risk. The anesthetic agents depress vital protective reflexes and render the patient unable to maintain respiratory function. Thus, monitoring has a central role in the intraoperative phase (Iivanainen et al 2012, 481.) A properly trained health care professional such as anesthesiologist or nurse anesthetist must be in charge of supporting the vital functions of a patient under general anesthesia (World Health Organization). It is a key principle in anesthesia that the patient is never left alone and unattended (Lukkari et al 2007, 305). The monitoring of an anesthetized patient aims at prevention of complications, early recognition of imminent changes, and timely delivered care. The extent of monitoring depends on several factors such as the patient's state of health and the anesthesia method used. In addition, the operation in question, its scale and duration significantly affect the monitoring. (Lukkari et al 2007, 305-307.) The patient should be observed before the induction of anesthesia to get start values. Later in surgery these can be used as a reference point to which changes are compared. Finally, although a plethora of technical means of measuring vital functions exist, the traditional ways of ascertaining the patient's welfare are not to be neglected. Traditional clinical monitoring is direct observation of the patient for abnormal physiological events. Monitoring literally signifies looking at the patient. This includes using the senses of hearing, touch, sight, and smell. Examples of clinical monitoring are auscultation by stethoscope of the correct placement of intubation tube, palpation of the pulse from the radial artery, feeling the chest for respiratory movements, touching the extremities for temperature, and looking at the pupils to evaluate the depth of anesthesia. Abnormal smells can be caused by leaking anesthetic gas. The nurse anesthetist should always have access to the patient and the monitors. The drapes should be arranged so that they provide a clear view of the patient and enable clinical monitoring. (World Health Organization.)

## 2.1 Recommendations of Monitoring in Anesthesia

The Finnish Society of Anaesthesiologists has produced guidelines for monitoring during anesthesia and surgery (Table 1). The guidelines have been drafted as an effort to standardize patient monitoring and promote patient safety. Recommendations for monitoring in general anesthesia are divided into the components of oxygenation, ventilation, circulation, temperature, muscle relaxation, concentration of anesthesia gases, and alarms. Clinical monitoring was included in all components.

(Salmenperä & Yli-Hankala 2006, 362 : Jalonen, Lindgren & Aromaa 2006, 50-52.)

**TABLE 1 Recommendations for Monitoring in General Anesthesia**

	Monitoring target	The Execution
<b>Oxygenation</b>	<ul style="list-style-type: none"> <li>-Inhaled anesthesia gas concentration</li> <li>-Blood oxygen concentration</li> <li>-Tissue oxygenation</li> <li>-Changes in the oxygen consumption</li> </ul>	<ul style="list-style-type: none"> <li>-Measuring the oxygen concentration in the inhaled gases</li> <li>-Using Pulse Oximetry</li> <li>-Blood gas analysis as needed</li> <li>-Using monitors with alarms</li> </ul>
<b>Ventilation</b>	<ul style="list-style-type: none"> <li>-The carbon dioxide concentration in the exhaled air (etCo2)</li> <li>-Changes in the Co2 production</li> </ul>	<ul style="list-style-type: none"> <li>-Ensuring the correct placement of the intubation tube by auscultation</li> <li>- Constant measuring of etCo2</li> <li>-Following the inhaled Co2 in a machine with rebreathing system</li> <li>-Blood gas analysis as needed</li> </ul>

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(Continues)

	Monitoring target	The Execution
<b>Circulation</b>	-Adequate circulation	-Blood pressure and pulse measurements at least in 5 minute intervals -Constant ECG measuring -Pulse oximetry -Monitoring diuresis -Measuring peripheral temperature -Invasive blood pressure monitoring as needed
<b>Temperature</b>	-Maintaining optimal temperature	-Following the effect of used heating methods -When needed, invasive monitoring of core temperature
<b>Muscle Relaxation</b>	-Optimal muscle relaxation needed for the operation -Prompt recovery of muscle tonus	-Use of peripheral nerve stimulation
<b>Concentration of Anesthesia Gases</b>	-Optimal administration of anesthetic gases	-Measuring the concentration of anesthesia gases in inhalation and exhalation
<b>Alarms</b>	-Notice changes in vital functions	-Sound alarm for at least to the lower limits of apnea, minute ventilation, and inhaled oxygen concentration -alarms for the lower limits of Spo <sub>2</sub> , Pulse, Blood pressure, and etCo <sub>2</sub>

(Jalonen, Lindgren &amp; Aromaa 2006, 50-52.)

## 2.2 Monitors

The variety of patient monitors has diversified in recent years which have enabled more detailed observation of physiology. However, the risk to misinformation and misinterpretation has increased in kind. Understanding the monitor's functioning allows the user detect when the machine is not working properly or produces unreliable results. In general, a monitor is a machine that consists of the following components: a device attached or connected to patient, a measuring device that converts the detected information into an electrical signal, a computer that processes the signal, and a display showing the measured variable in a numeric form or a shape. (Aitkenhead, Smith & Rowbotham 2007, 345-346.) The nurse anesthetists and anesthesiologist form a crucial link between the machine and the patient (Salmenperä & Yli-Hankala 2006, 361-362). Essential features in monitoring are the ability to interpret the machine-produced complex clinical data, recognize threatening changes, and take necessary measures to correct the situation (Ferns, Harris, McMahon & Wright 2010).

Monitors include alarms that by sound react to values over or under the set limits. The limits are part of the machine's basic functions and set by the manufacturer. Children and adult patients have their own set alarm limits. These are changed and modified by the user to suit for individual patients. Alarms are important as they draw attention to developing physical changes and need to secure the patient's vital functions. It needs to be acknowledged, however, that the information given by a machine is open to interpretations and false readings do occur. Artifact from electrical interference such as surgical diathermy or movement triggers false alarms. (Aitkenhead et al 2007, 347,368.) The reason for an alarm, even a false one always has to be found out. The nurse anesthetist should monitor both the patient and the machine, make comparisons, and form a holistic understanding of the situation. (Lukkari et al 2007, 306-307.)

## 3 Circulation

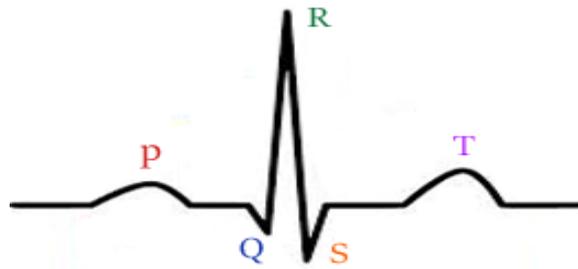
The cardiovascular system consists of the heart, the blood, and the blood vessels. Heart, the muscular pump must constantly push blood into the

vessels in order that oxygen and nutrients are delivered to the cells to keep them alive. The heart's left side pumps oxygen-rich blood from the lungs to the systemic circulation. After unloading O<sub>2</sub> and nutrients the blood then picks up waste products such as carbon dioxide (CO<sub>2</sub>) and delivers them back to the right atrium. The right side of the heart takes the blood from systemic circulation to pulmonary circulation. In the lung's capillaries the unloaded CO<sub>2</sub> is exhaled and inhaled O<sub>2</sub> collected. The freshly oxygenated blood then travels again to the left atrium. (Tortora & Derrickson 2009, 717,728.) The principle aim in anesthesia monitoring is to ensure oxygen delivery to the tissues (Aitkenhead, Smith & Rowbotham 2007, 348). It is necessary to monitor the patient's circulation during anesthesia as the anesthetics and surgery change hemodynamics (Lukkari et al 2007, 312). Cardiac function during anesthesia is evaluated by different blood pressure monitoring techniques, studying the pulse and the electrical function of the heart, using oxygen saturation meter, checking peripheral perfusion, and following the breathed out CO<sub>2</sub> values (Lee 2009, 16).

### **3.1 ECG (Electrocardiography)**

ECG records the heart's electrical currents as the heart muscle fibers produce action potentials with each heartbeat. In brief, ECG can be said to describe the electrical function of the heart. (Tortora & Derrickson 2009, 735). ECG is a standard monitoring procedure for each patient. The purpose of ECG is to observe the heart's function, detect cardiac problems, arrhythmias, ischemic changes or other deviations. In normal surgical conditions, three leads are placed on the patient: red on the right side, second intercostal space on the sternum, yellow on the left side correspondingly, and green on left side. The electrodes should be connected to the patient before the induction of anesthesia to give a reference point for the future readings. (Lee 2009,16.) A visual representation of the heart's function can be seen on the monitor's screen. The waves in a normal sinus rhythm are P, Q, R, S, and T (Figure 2) (Encyclopedia of Surgery). The machine detects deviations in the ST levels and alerts the user; elevation or depression in the ST point to ischemic changes in the heart muscle (Salmenperä & Yli-Hankala 2006, 345). It should be remembered that ECG use is restricted to the electrical function of the heart; it does not tell about the mechanical function and cannot assess the

cardiac output or blood pressure (Lee 2009, 16). ECG can also produce artifact, a false interpretation resulting from interference to the signal. The reason for artifact can be a moving patient, displaced electrode or the use of surgical diathermy. (Aitkenhead et al. 2007, 347-348.) The pulse figures given by ECG should be compared to the pulse oximetry's readings. Also radial pulse ought to be palpated as a reference. (Lukkari et al. 2007, 313.)



**FIGURE 2 Normal Sinus Rhythm**

## 3.2 Blood Pressure

Blood pressure is the force blood exerts on the walls of blood vessels with every heartbeat. Systolic blood pressure tells the highest pressure in the arteries when the heart contracts. Diastolic blood pressure is the lowest pressure in the arteries when the heart is at rest between contractions. Blood pressure is controlled by several interconnecting negative feedback systems such as the cardiovascular center in the brain's medulla oblongata, baroreceptors and chemoreceptors in the aorta and carotid arteries, and hormonal regulation. These systems adjust to changes in blood pressure by regulating the heart rate, stroke volume, blood volume, and vascular resistance. (Tortora & Derrickson 2009, 772-779).

### 3.2.1 Non-invasive Blood Pressure (NIBP)

In the operating room automated oscillometer (blood pressure measuring device) is used. The cuff is attached on the left arm if possible and the hand placed at heart level. The cuff is typically automated to inflate in 5 minute intervals. Additional measurements are made as necessary. (Salmenperä

&Yli-Hankala 2006, 346.) Correct cuff size ensures reliable measuring results. Too small cuff distorts the results upwards resulting to interpretation of high blood pressure. Too large cuff cannot achieve necessary pressure resulting to false low measurements. Changes of surgical position reflect to changes in blood pressure. (Liukas Niiranen & Räisänen 2013.) Baseline blood pressure value is needed for determination of hypo- or hypertension. Measurements taken before the induction of anesthesia and administration of drugs provide crucial information on hemodynamics prior to affecting surgical variables. The limit values of low or high blood pressure are individual. Consequently, the alarm limits are accustomed for each individual patient. (Kalezic et al 2013.) Intraoperative hypotension is caused by anesthetics that induce vasodilation and consequently lower blood pressure. Other reasons for hypotension during surgery can be loss of blood and resulting hypovolemia, dehydration, low cardiac output or vascular resistance. Also multiple trauma, burns, and shock cause considerable hypotension. (Bryant & Bromhead 2009, 1-6.) Limits for hypotension depend on clinical findings such as the level of consciousness, diuresis, and potential cardiac ischemia. As a rule, generally healthy people endure lower blood pressure better than people with multiple illnesses and those suffering from cardiac conditions. Normally hypertensive patients can manifest clinical findings related to lowered blood pressure with blood pressure values considered as regular. (Liukas et al 2013.) In general, intraoperative hypotension can be defined as a 20% decrease in systolic blood pressure from the baseline value (Kalezic et al 2013). Hypotension is managed by temporarily increasing the flow of i.v fluids and giving a bolus of antihypotensives such as etilefrine or phenylephrine (Bryant & Bromhead 2009, 1-6). Hypertension during anesthesia can result from pain, inadequate level of anesthesia, hypoxia or hypercarbia (raised amount of CO<sub>2</sub> in the blood). To correct the homeostatic imbalance, the patient is alternatively given more analgesics, the anesthesia is deepened, or the ventilation corrected. (Saddler 2009, 11-13). Under anesthesia, fluctuation in blood pressure also reflects the depth of anesthesia in relation with response to surgical stimulation (Lukkari et al. 2007, 243). Disadvantages of non-invasive blood pressure measuring are inaccuracy during arrhythmias and inability to have continuous measurement (Mendonca 2006, 6).

Mean Arterial Pressure or MAP is the average blood pressure prevailing in the entire cardiac cycle. It also represents perfusion pressure, a pressure that is needed for tissue and organ perfusion and cellular oxygenation. (Bradshaw 2012.) With hypotensive patients MAP provides better indication of perfusion than diastolic or systolic pressures (Ferns T. et al 2010, 42.) MAP is calculated by a formula of diastolic BP +  $1/3(\text{systolic BP} - \text{diastolic BP})$  (Tortora & Derrickson 2009, 773). Anesthesiologist may give a target MAP as a goal-directive therapy. This helps the anesthesia nurse to respond pharmacologically to support the patient's vital functions. Adequate MAP ensures circulation and perfusion of the brain tissue (Nieminen 2009). A typical MAP limit is 60-70. (Ferns T. et al 2010, 42.)

### **3.2.2 Invasive Blood Pressure Monitoring**

Invasive methods of measuring blood pressure are used when information of the patient's circulation is needed in real time. In general these are high risk anesthesia patients, patients with cardiovascular diseases or trauma, and patients who have multiple chronic conditions. (Lukkari et al 2007, 312-313.)

In order to measure arterial pressure, an artery is cannulated. Commonly the radial artery is used. To prevent blockage, a heparinized saline drips through the transducer (a device that changes liquid's movement to an electrical signal) flushing it. One advantage of the arterial cannula is the possibility to draw blood samples for arterial blood gas analysis or other use. The use of the arterial cannula is a common practice with severely ill patients both intraoperatively and in the intensive care unit. (Aitkenhead et al. 2007, 348-349.) The risks of arterial pressure monitoring include infection, hematoma, bleeding, thrombosis, and nerve damage. False readings may be due to equipment misuse; the catheter is kinked, the transducer is at an incorrect level or is calibrated incorrectly. (Reich, Kahn, Mitnacht, Leibowitz, Stone & Eisenkraft 2011, 51-52.)

Central venous pressure (CVP) is measured by catheterizing a vein leading directly to the heart. Typically the subclavian or jugular vein is used. This catheter is called central venous catheter or CVC in short. Central venous pressure is used to estimate the pressure in the right atrium where the blood

returns from the systematic circulation. In short, CVP predicts the function of the heart's right side but also gives indications of blood volume, venous return, and intrathoracic pressure. (Hocking 2009). CVP levels can be included in the planning of fluid and electrolyte balance (Lukkari et al. 2007, 314).

To measure the pressure inside pulmonary artery, a catheter called Swan-Ganz is inserted into the vena cava and from there fed into the pulmonary artery. (Aitkenhead et al. 2007, 351- 352). The pulmonary artery catheter is often used for critically ill patients when constant feedback of hemodynamics is needed and less invasive means are excluded. Some pulmonary arterial pressure (PAP) measuring are complications related to insertion, ventricular arrhythmias, and displaced or knotted catheters. (Evans et al. 2009).

### 3.3 Pulse

Pulse is the traveling pressure wave after each contraction of the heart's left ventricle; the arteries expand and then recoil. The pulse is best palpated in arteries near the surface of the body. These are for example the radial and the carotid artery. At rest the pulse rate normally varies from 70 to 80 beats per minute. Tachycardia means rapid resting pulse or pulse exceeds 100 beats per minute. Bradycardia is pulse rate of 50 beats or less per minute or slow resting pulse. (Tortora & Derrickson 2009, 780.) Heart rate instead is the amount the heart beats in a time unit, usually a minute and marked as bpm (beats per minute). Normally, pulse and heart rate correspond to each other if the patient does not suffer from certain heart conditions. Thus, they are often used as synonyms. (MNT 2013.) In the operating theater variations in pulse between individuals result from age, physiological factors, and the method of anesthesia. A rise in the pulse can indicate too light anesthesia or inadequate analgesia meaning that the patient feels pain. Other reasons include less carbon dioxide exiting the patient, loss in blood volume and raised body temperature (fever). Falling pulse may be an indication of too deep anesthesia or a late stage of considerable hemorrhage. (World Health Organization.)

### 3.4 Fluid Balance

The aim of fluid therapy during anesthesia is to maintain adequate circulating blood volume, renal function, oxygen delivery to tissues and electrolyte balance. Basic daily needs, too, need to be covered (TABLE 2).

**TABLE 2 Daily Fluid and Electrolyte Requirements of an Adult**

Water	30-50 ml/kg
Glucose	1-1,5 g/kg
Sodium	1-2 mmol/kg
Potassium	0,5-1,5 mmol/kg
Magnesium	0,15 mmol/kg
Calcium	0,15 mmol/kg
Phosphate	0,3 mmol/kg
Chloride	1-2 mmol/kg

(Tunturi 2013b)

This is achieved by replacing already existent losses and providing maintenance fluids. (English, English & Wilson 2009.) During the intraoperative care patients lose fluid due to hemorrhage, losses to the third space and dehydration. Dehydration results from fluid loss by vaporization from the skin, the lungs, and the operated area as well as preoperative fasting. (Korte, Rajamäki, Lukkari & Kallio 1996, 401.) Most commonly administered fluids during the intraoperative phase can be categorized into basic and replacement fluids. Basic fluids include 5-10% glucose with or without a sodium and potassium addition. Anesthesia and surgical trauma cause metabolic changes in the insulin regulation which raise the blood glucose levels. If a glucose based replacement fluid is used, blood sugar levels can raise to exceed 10 mmol/l. Thus, glucose infusion is mainly used for the prevention of hypoglycemia in diabetic patients. Replacement fluids resemble by their electrolyte consistency the body's own fluids; these are Ringer-Acetat® and physiological NaCl. (Salmenperä & Yli-Hankala 2006, 331, 334.) For minor blood loss a crystalloid electrolyte solution such as

Ringer-Acetat® is used as a replacement fluid while major blood losses are replaced with transfused units of red cells. (Aitkenhead et al. 2007, 420.) When planning fluid therapy, several factors need to be taken into account. The basic fluid need of an adult is 2ml/kg/hour. Additional needs total 4-10ml/kg/hour on average depending on the amount of lost fluid. Potential losses due to diarrhea, vomiting and fever should also be considered. The age, size and medical conditions of the patient affect fluid therapy. Fluid balance is monitored by examining blood pressure, pulse rate, respiratory rate and urine output. Losses to other catheters or drains should also be taken into account. Blood gas analysis taken from arterial blood provides valuable information on the acid-base balance, respiratory function, and metabolic state. Electrolyte and fluid imbalances are corrected by adjusting the fluid therapy. (Lukkari et al. 2007, 314-317.)

Maintaining functional blood capacity in the heart supports the body's ability to cope with the surgical stress. The blood capacity is perceived with filling pressure and end-diastolic pressure. The pressure in the pulmonary artery is created by the capillary circulation in the pulmonary arteries and the pressure prevailing in the left atrium. Pulmonary artery catheterization is commonly used for critically ill patients with cardiac complications. It enables monitoring the function of the heart's left side and helps detect left atrium failure. Response to fluid therapy can rapidly be detected from the measured values. PCWP reflects filling pressure of the left atrium. Measuring PCWP is an invasive procedure. The pulmonary artery is cathetered with a balloon-tipped multi-lumen Swan-Ganz's catheter. A balloon at the end of the catheter is inflated, wedging it into a hold inside the artery. (Salmenperä & Yli-Hankala 2006, 349-351,364).

### **3.5 Temperature**

Recommendation is that the patient's temperature is monitored in all surgical procedures lasting longer than 30 minutes. Both core and peripheral temperatures should be measured. (Poikajärvi 2013.) The body's normal core temperature ranges from 36 to 37 °C. In the peripheries the temperature is 2-4°C lower than in the core and the skin is ever cooler. (Kokki 2013.) In normal conditions a 0,5-1 °C variation in the core temperature triggers physiological

responses to regain the balance. In hypothermia this means peripheral vasoconstriction and shivering while in hyperthermia dilation of blood vessels and sweating. Due to anesthesia the body's ability to regulate the core temperature is delayed and decreased. According to different sources 50-90% of patients suffer from perioperative hypothermia. (Poikajärvi 2013.) Hypothermia predisposes the patient to infections and cardiac problems. Surgical wound healing slows down and unwanted changes occur in blood coagulation, blood viscosity, and platelet function. In addition, the time the body takes to metabolize and secrete drugs lengthens which results in longer hospital stays. (Kokki 2013). A common place of measuring temperature is the auditory canal. Core temperature measuring is always an invasive procedure. Temperature taken from the pulmonary artery indicates the temperature of the circulating blood. Thermometer in the lower part of esophagus measures the temperature of the heart and monitoring temperature from the nasopharynx reflects the temperature of the brain. Urinary bladder is also used as a core temperature measurement place but is susceptible to diuresis. (Poikajärvi 2013.) Intraoperative thermal management is conducted by using heaters, thermal mattresses, infusions and fluids warmed to 37 °C, and thermal suits. (Kokki 2013).

### 3.6 Diuresis

Diuresis, the excretion of urine is monitored in surgical patients to estimate fluid balance, hemodynamic stability, and kidney function (Niemi-Murola et al 2012, 89,122). Urine output is measured and documented cumulatively. This provides information of hourly urine output as well as the total amount of excretion. Hourly urine output of 0,5-1ml/kg is considered a norm.

(Lukkari et al. 2007, 325-326.) During the intraoperative phase reduced diuresis can result from circulatory, cardiac or hormonal changes. More rarely the cause is renal damage. Increased output of urine instead tells about heavy osmolar load. Indications for diuresis monitoring are urological, cardiologic, neurological, and vascular operations or other extensive procedures. In addition, time consuming surgeries, hypovolemia, acute kidney failure, heart failure, prolonged state of hypotension, and shock are causes for monitoring the urine excretion. (Salmenperä & Yli-Hankala 2006, 360).

## 4 Respiration

The body's cells need continually oxygen for metabolic reactions. These reactions produce a waste product called carbon dioxide. The respiratory system exchanges these two gases by supplying air and eliminating  $\text{CO}_2$ . The cardiovascular system participates in the transportation of the gases from the lungs to the tissues and back. (Tortora & Derrickson 2009, 874, 890.)

During general anesthesia, the most important object of monitoring is respiration. The anesthetic agents cause respiratory depression and muscle relaxants the loss of respiratory muscle tonus. The airway must be secured and maintained by an artificial airway management device, most commonly intubation tube or laryngeal mask (LMA). (Lukkari et al 2006, 308.) The breathing function is wholly or partially performed by a machine that delivers oxygen and anesthetic gases; from exhalation the machine collects and removes carbon dioxide. The direction of the gas flow is controlled with unidirectional valves. In the commonly used circle system the gases are circled and rebreathed in part. The security of breathing system needs to be monitored during operations and checked before every use. (Aitkenhead et al 238-243.) Attaching the patient to ventilator does not remove the responsibility of monitoring the machine. The respiratory function needs to be monitored constantly by observing the patient and processing information from the displays. (Salmenperä & Yli-Hankala 2006, 339, 308.) Monitoring of respiration can be divided in to the observation of the gas exchange and ventilation (Niemi-Murola, Jalonen, Junttila, Metsävainio & Pöyhiä 2012, 18). In addition, the airway pressure and gas concentrations are observed. These are discussed in the following chapters.

### 4.1 Gas Exchange

Gas exchange monitoring consists of ensuring oxygenation of tissues and ventilation. Oxygenation is measured by oxygen saturation and ventilation evaluated by the amount of expired carbon dioxide. (Aittomäki, Valta & Salorinne 2006, 190-191.)

### 4.1.1 Oxygen Saturation SpO<sub>2</sub>

The oxygen in blood is stored in haemoglobin. The binding of oxygen to haemoglobin is called oxygen saturation as the haemoglobin molecule is saturated with oxygen molecules. Oxygen saturation is measured with a pulse oximeter and represented in percentages. (Wilson 2009.) Measuring oxygen saturation is a standard anesthesia practice as it gives constant information in a non-invasive way of cardio-pulmonary function, tissue perfusion, and the pulse (Vijaylakshmi 2002, 261-266). The oximeter is attached to the tip of a finger, earlobe or nose. The device has a probe with two light-emitting parts that shine through tissue, register the haemoglobin concentration and convert it into figures. During anesthesia SpO<sub>2</sub> should measure between 95-100%. Saturation percentage of 92 or under is considered hypoxia, inadequate concentration of oxygen in the blood and disrupted tissue perfusion. (Lukkari et al 2007, 243-244.) Patient with good perfusion has pink lips and tongue. Hypoxia is shown by pale, even bluish coloring. Visual detection of hypoxia is more difficult in dark skinned patients. (Wilson 2009.) The pulse oximeter requires good peripheral pulse waveform for detection. This may cause a problem with patients who have poor peripheral perfusion. In addition, nail polish and synthetic nails interfere the signal and may give false readings. If possible, the oximeter should be placed on a different arm from the blood pressure cuff. The inflating cuff temporarily blocks the circulation on the arm and the oximeter registers artifact. (Vijaylakshmi 2002, 261-266.)

### 4.1.2 etCo<sub>2</sub>

Ventilation means the body's ability to remove carbon dioxide, the waste product of respiration (Niemi-Murola et al 2012, 19). Carbon dioxide is then a prominent regulator of respiration (Liukas et al 2013). The adequacy of ventilation is assessed by measuring the carbon dioxide concentration of the exhaled air. This value is shortened as etCo<sub>2</sub>. Capnography attached to the breathing tube analyzes the carbon dioxide from the breathed air. The capnograph draws a curve where the exhalation is seen as a wave-like form and the inhalation as a flat zeroing line. One curve represents one respiratory cycle. (Salmenperä & Yli-Hankala 2006, 340-341.) In normoventilation etCo<sub>2</sub> is between 4,5 and 5,5. In addition, the amount of inflowing CO<sub>2</sub> (FiCo<sub>2</sub>) is

followed to prevent in the accumulation of carbon dioxide in the blood stream. The absorbers that removes  $\text{CO}_2$  from the exhaled gas should be removed no later than when the  $\text{FiCO}_2$  value is 0,5%. (Liukas et al 2013.)

## 4.2 Ventilation

Pulmonary ventilation is the exchange of oxygen between the atmosphere and the lung alveoli. This is achieved with the alternative contraction and relaxation of the respiratory muscles and the resulting pressure differences. The rate of inhaled oxygen and the breathing work required from the lungs are influenced by the lung compliance and airway resistance. (Tortora et al 2009, 890.)

A basic measure of respiratory function is the respiration frequency, also called respiratory rate. The respiratory rate is monitored to recognize pulmonary insufficiency and apnea. (Lukkari et al 2006, 309.) The respiratory rate announces the amount of breaths taken in a minute. This can be calculated either by feeling the chest movements or from the capnograph readings. For adults, in normoventilation respiration frequency is 10-20 per minute. Increased respiratory rate tells of greater breathing effort and possible disruption of gas exchange. (Niemi-Murola et al 2012, 18.) The respiration rate can be timed from the anesthesia machine. Tidal volume (TV) measures the amount of gas delivered into the lungs in one breath. In an average sized adult TV is 500 ml. (Tortora & Derrickson 2009, 894.) With an intubated patient the amount of inflowing and out coming gases needs to be monitored to ensure adequate ventilation and prevent hypoxia (Salmenperä & Yli-Hankala 2006, 339). Minute volume (MV) describes the amount of gases the patient breathes in a minute. MV is measured as millilitres per minute. The ventilator settings are regulated on the basis of either TV or MV measures. (Lukkari et al 2006, 160).

## 4.3 Airway Pressure

Airway pressure is the amount of work the lungs need to do in order to deliver a breath. Airway pressure monitoring is needed on one hand to avoid lung trauma from excessive pressure; and on the other hand to ascertain that a necessary amount of pressure stays in the lungs preventing the alveoli from

collapsing. A pressure monitor is incorporated into the ventilator. (Aitkenhead et al 2007, 355.) In average, airway pressure ranges between 10-25 cmH<sub>2</sub>O. Factors affecting the airway pressure are the size of the intubation tube in relation to the set gas volume values. Pressure changes during anesthesia can result from obstruction in the airways or leakage from the breathing system connectors. In addition, secretions in the airways, decreased lung compliance, and raised intrathoracic pressure increase the respiratory work. The values PEAK, PLAT, and PEEP are used to describe the prevailing airway pressures. (Liukas et al 2013.) Peak Inspiratory Pressure is the maximum pressure in a single ventilator delivered breath. Plateau Pressure or PLAT is the pressure in the lungs at the end inspiration when there is no active gas flow from the machine. (Butcher & Boyle 1997, 6, 9.) PEEP is shortened from Positive End-Expiratory Pressure. In anesthesia PEEP is used to prevent atelectasis, the collapse of the lung alveoli. Atelectasis during anesthesia may be caused by decreased respiratory muscle tone due to the administered drugs. The positioning of the patient can be another factor. For instance, when the patient lies supine on the operating table the intrathoracic pressure increases and the airways are compressed. By applying PEEP, the alveoli are held open at the end-expiration preventing the total collapse of the lungs. In practice this means mechanically keeping positive pressure in the lungs by adjusting desired values to the anesthesia machine. PEEP increases lung compliance and prevents impaired gas exchange. Indications for the use of PEEP are obesity and lung disease. (Imberger, McIlroy, Pace, Wetterslev, Brok & Møller 2010.)

#### 4.4 Concentration of Gases

Inhalation anesthetics come in liquid form. Vaporizer is the part of anesthesia machine that vaporizes the inhalation anesthetics and conveys them in appropriate concentrations to the patient. (Lukkari et al 2006, 160.) The machine's flow meter can distinguish and measure the concentrations of not only the inhalation anesthetics but the administered oxygen, nitrous oxide, and carbon dioxide. The concentrations are presented in percentages. The gas concentration is monitored to maintain the desired depth of anesthesia and avoid too light anesthesia. By following the oxygen concentration, the delivery of air into the patient is ensured and hypoxia prevented.

(Salmenperä & Yli-Hankala 2006, 340-342.)

#### 4.5 Clinical Monitoring of Respiration

For safe anesthesia, respiration monitoring is complemented by clinical studying of the patient. The respiratory movements are observed to ensure that the airway remains open. The motion of the chest should be symmetrical and regular. The intubation tube has to be fixed securely to prevent its displacement. (Lukkari et al 2006, 308-309.) The pressure in the tube's cuff needs to be checked regularly with a cuff pressure meter. Overinflated cuff can cause airway obstruction and underinflated one does not seal the trachea effectively. (Aitkenhead et al 2007, 254-255.) Respiratory sounds should resonate clean and clear. Both sides of the lungs ought to be auscultated by stethoscope. Signs of hypoxemia can be seen from the skin, lips, and nails. However, cyanosis is visible not until the oxygen saturation drops to under 80%. Ruddy complexion instead can be a mark of increased blood carbon dioxide. (Hoikka 2013.) Formation of vapor in the intubation tube is a mark that oxygen indeed flows into the lungs (Lukkari et al 2006, 309).

### 5 Depth of Anesthesia

Depth of anesthesia is a compound of hypnosis, antinociception, suppression of reflexes, and amnesia. Due to its nature, anesthesia depth monitoring requires an indirect parameter. The focus of the monitoring is on the level of hypnosis. (Bruhn, Myles, Sneyd, & Struys 2006.) Naturally, the concentrations of administered anesthetic agents correlate with the level of hypnosis but this does not provide actual means of reliable measuring. Clinical signs of inadequate depth of anesthesia are raised blood pressure level, increased heart rate, and lacrimation. However, these alone are insufficient parameters. (Bruhn et al 2006.) Using monitors that estimate the rate of awareness has been shown to reduce intraoperative drug use, speed recovery from anesthesia, and prevent complications such as postoperative nausea and vomiting (Musialowicz & Pölönen 2001).

Electroencephalography or EEG is utilized in the evaluation of the hypnotic component of anesthesia. EEG records the electrical activity of the cerebral cortex via scalp-attached electrodes. (Wennervirta 2010, 1, 22-23.)

Bispectral Index Monitor or BIS is an EEG based monitor. Three to four electrodes applied to the forehead register EEG signal. (Bruhn et al 2006). BIS values range from 0-100, 100 indicating a totally awake and orientated patient and 0 a deeply anesthetized one. Adequate depth of anesthesia for surgical operation is between 40-60 BIS. (Kymäläinen 2009.) Although BIS is considered a fairly reliable meter in the operating theater conditions, different anesthetics, hypoxemia, and status epilepticus may interfere the readings (Aitkenhead et al 2007, 359). Minimum alveolar concentration or MAC is used as an indicator of satisfactory concentration of inhaled anesthetics to produce the wanted depth of anesthesia. MAC of inhaled anesthesia gases is 1 when 50% of subjects do not produce reflex response to surgical incision. (Golembiewski 2012.)

## **6 Pain**

Patients have both juridical and ethical right to good pain management. The principle is that the patient should be as free of pain as possible. Traditional methods of pain assessment such as the visual analog scale (VAS) or numeric rating scale (NRS) do not apply to a patient under general anesthesia (Aitkenhead et al 2007, 515.) As there is no machine to monitor pain, vital signs and the patient's outer physical signals need to be inspected. Raised blood pressure and pulse can tell of experienced pain. Clinical signs include sweating, lacrimation, and creased forehead. (Lukkari et al 2006, 320.)

Anesthesiologist plans the drug therapy based on the surgery in question, patient's overall condition, and individual factors such as age, weight, and possible allergies (Lukkari et al 2006, 371). In intraoperative drug therapy forethought and anticipation is needed. Patient should be given analgesic before pain is felt. This calls for regular pharmacologic intervention. Adequate dosing is necessary to ensure lack of pain. Response to the therapy should be monitored from the vitals. (Iivanainen, Jauhianen & Syväoja 2012, 500.) In general anesthesia strong opioids such as fentanyl or remifentanyl are used intravenously. These analgesics produce strong but short effect which is why

they need to be administered regularly. Remifentanyl is normally given as an infusion while fentanyl usually in boluses. (Salomäki 2006, 133.) Analgesics can be also administered to the epidural space via a preoperatively placed catheter. Local anesthesia techniques complement the pain treatment. They as well as the epidural catheter help in the postoperative care. Good pain management reduces the burden to cardiovascular system, expedites recovery, and reduces postoperative complications (Op cit 2012, 500, 828.)

## **7 Muscle Relaxation**

The level of muscle relaxation is monitored to optimize the time for intubation, to determine necessity for medication, and estimate recovery from the administered muscle relaxant. The muscle relaxation agents given in anesthesia inhibit the progress of electrical action potentials to the muscle fibers. Muscle relaxation monitoring is based on electrical stimulation of peripheral nerves and the received muscle response. In nerve stimulation a stimulus up to 70 mA is given to a motoric nerve and the associated muscular response is monitored. Usually the ulnar nerve is used and the response can be seen in the adductor muscle of the thumb. The current is given transcutaneously with applied ECG electrodes. (Illman 2012.) Neuromuscular transmission monitor or m-NMT is the module used in measuring the effect of neuromuscular blockers (Dahaba, von Klobucar, Rehak, & Werner 2002). Train-of-four (TOF) a quantitative stimulation method where four stimuli of equal strength are given to a motor nerve in a sequence. If the muscle relaxation is total there is no muscle response. With the effect of pharmacological muscle relaxant fading, responses in the form of muscle twitches begin to appear. Finally, as the relaxation is over all four stimuli receive response. (Niemi-Murola et al 2012, 90.)

## **8 Position**

The aim of patient positioning in surgery is to provide optimal access to operate for the surgeon while protecting the patient from potential risks. The surgical position is a point of concern as the anesthetics depress hemodynamics and pulmonary function. For instance, in some positions the

accumulation of blood to the lower limbs results to decreased venous return and a thrombosis risk. The pulmonary functional capacity is reduced by the prone position and anesthetics by as much as 1000ml which creates a considerable threat of disrupted gas exchange and atelectasis. (Rotko 2010, 312-318). Safe positioning requires good communication and co-operation between the surgeon, anesthetist, and nurses. In the beginning and end of the operation there needs to be enough helping hands when the unconscious patient is positioned or moved. Knowledge of physiological changes caused by a surgical position helps the planning and prevention of injury to the patient. (Knight & Mahajan 2004.) Individual factors such as weight and height, illnesses, physical movement restrictions, and prostheses have to be debated in the planning (Korte et al 1996, 368).

Patient under anesthesia is susceptible to indirect trauma caused by inconvenient surgical position. These include injury to nerves, soft tissue, and muscles as well as pressure sores. Shearing of the skin and vascular problems may result from improper positioning. (Knight & Mahajan 2004.) Nurse anesthetist has to pay attention to the placement of the intubation tube, infusion lines, catheters and other equipment attached to the patient. The position of the patient has to be regularly checked and changed when necessary. In long surgeries the head and extremities should be moved or their place shifted to prevent injury, pain, and numbness. (Lukkari 2007 278, 286-287.)

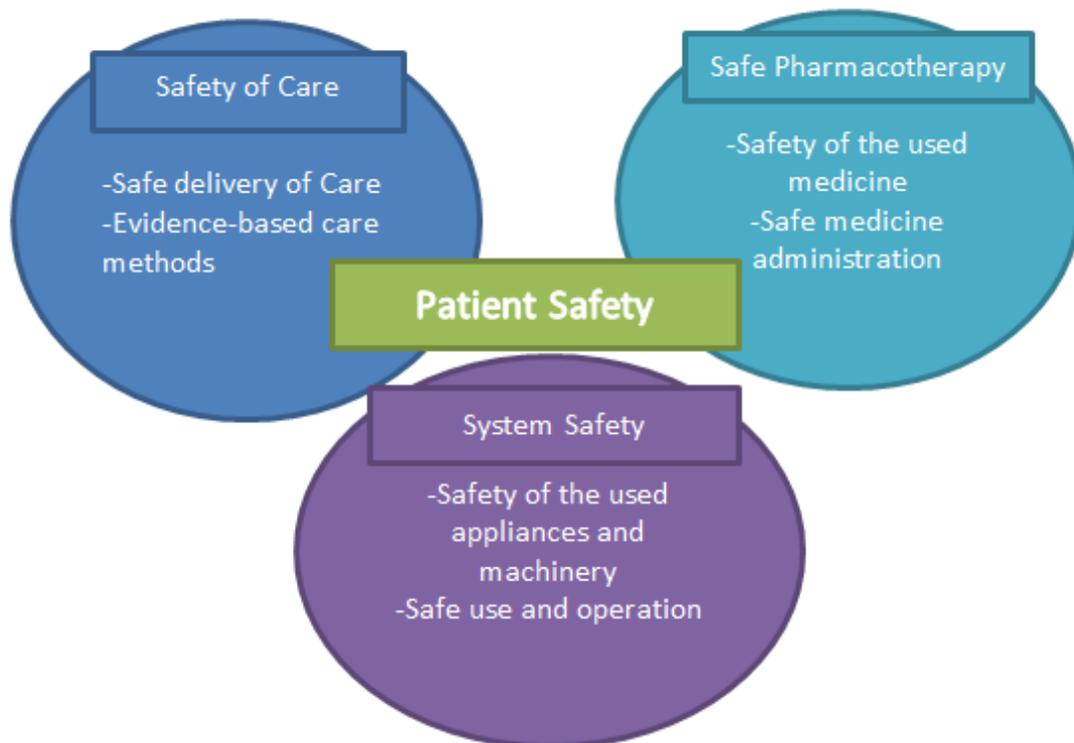
## **9 Documentation**

Patient documents are juridical records. The purpose of documentation is to ensure the safety and continuity of care. During the intraoperative phase a manual or electronic anesthesia form is used. (Iivanainen et al 2012, 489.) When manual documentation is used, the nurse anesthetist does the recording of the information to a manual form by hand. In electronic documentation the machines automatically save data and log it into recording systems (Aitkenhead et al 2007, 366). The nurse anesthetist registers administered drugs, fluid therapy and diuresis in the form. In addition, possible blood sugar measurements taken during anesthesia are marked. Other anesthesia related factors that need to be entered to the recording system are

the form of anesthesia and used equipment such as the size of laryngeal mask. (Op cit. 2012, 489). At the end of the surgical procedure, the nurse anesthetist takes instructions for follow-up treatment from the surgeon and marks the amount of hemorrhage to the documentation system. (Lukkari et al 2001, 305). It is important to have documentation of complications in the anesthesia that detail the incident. These need to be taken not only as a legal responsibility to do so but so that in future precaution can be taken. (Aitkenhead et al 2007, 369).

## 10 Patient Safety

Patient safety is in a central role in all areas of health care. In practice, patient safety is all those actions and principles taken to protect the patient from harm and deliver safe care. It is composed of safety of care, safe pharmacotherapy, and system safety (Figure 3).



**FIGURE 3 Patient Safety**

Most risk situations are preventable. Stumbling blocks are inadequacy or lack of communication, interrupted flow of information, and hurry. The consequences of compromised patient safety result to longer hospital stays and greater expenses to the national health care. This is without mentioning the harm to the patient and their next of kin. The importance of anticipating risk situations cannot be stressed. (THL.) Safety incidents are reported to the web-based HaiPro system. The reporting is confidential and does not seek to blame or discipline. Rather, the purpose is to learn from mistakes by processing and evaluating the situations. Knowing what went wrong and why helps to avoid similar incidents occurring in future. (HaiPro.)

In this chapter intraoperative patient safety and anesthesia practices are reflected. During anesthesia patient is administered strong and fast-acting drugs intravenously. This always includes the risk of life threatening complications. Taking care of the physical safety, the nurse anesthetist never leaves her patient alone. Systematic operating and routine actions are adapted to all anesthesia practices to avoid accidents from occurring. (Niemi-Murola et al 2012, 165.) The nurse anesthetist always does her routine in the same way and same order from the equipment checks to anesthesia preparations. In this way she ensures that no safety step is neglected. (Lukkari et al 2008, 136.) The safety steps include among other things testing the function of the laryngoscope, suction, intubation tube's cuff, and the anesthesia machine in use. Commonly occurring mistakes are medication related ones. To take preventive steps all syringes are marked with a named label that includes and strength of the active ingredient. An unknown syringe without a label invariably goes to pharmaceutical waste. When a drug is diluted or added to an infusion bag, a label providing information on the contents, amounts, patient's name, and the name of the adding person is filled and attached to the bag. (Op cit. 2012, 165.)

In the operating theater patient safety is promoted with the use of a surgical check list. The surgical checklist was established by the World Health Organization in cooperation with World Alliance for Patient Safety as an effort to reduce surgery related deaths and complications. (World Alliance for Patient Safety.) The checklist used in the Central Finland Central Hospital is

modified from the WHO's list to fit the hospital's purposes and customs. It is incorporated into the Leija electronic documentation system used in perioperative care. The checklist has timeouts at the patient admission to the operating room, before the incision, and prior the patient leaves the OR (World Alliance for Patient Safety). The role of the nurse anesthetist in Central Finland Central Hospital is to fill in the information described in the following paragraph. In the sign in the patient's identity and the surgical procedure are confirmed. The patient is enquired for known allergies to prevent harmful reactions to administered drugs or other used products. The possibility of a difficult airway is evaluated to avoid problematic intubation and prevent aspiration risk. The need for antibiotic prophylaxis is reviewed. The surgeon estimates the risk for blood loss exceeding 1000 ml and communicates it to the nursing staff. The nurse anesthetist prepares for replacing the fluid loss correspondingly. The nurse anesthetist ascertains whether there are any patient-specific concerns. She also informs the other team members does the patient have medications in use that increase the risk of hemorrhaging. This information is documented to the patient data. Near the end of the operation the nurse anesthetist enters care instructions given by the surgeon and possible need for antibiotics to the Leija system. The amount of blood loss is marked to the records. The use of surgical checklist ensures that important safety steps are taken to provide safe care. The checklist helps to minimize most commonly occurring but avoidable risks that endanger the health and well-being of surgical patient. (World Alliance for Patient Safety.)

## **11 The Aim and purpose of the Thesis**

The aim of the thesis was to increase nursing students' understanding and knowledge of intraoperative care and nurse anesthetists' work. In addition, the aim was to facilitate the work of the perioperative student mentors. The purpose was to create an informative guide to international students practicing in the Central Finland Central Hospital. The interest for doing the guide to international students was the shortage of material in English on the subject in the local hospital. The subject the thesis is current and necessary as there are roughly 60 international students practicing in the Central Finland Central

Hospital every year (Palovaara 2013). The usefulness of the produced material is its applicability to working life.

### **11.1 The Production of the Guide**

Guides are part of the literature subdivision of non-fiction. Non-fiction is a factual and informative form of writing. (Jussila 2008, 14-15.) Guide is defined as an informative book or pamphlet that gives advice, instructions or facts on a specific subject or activity (Dictionary.com). A good guide has a logic structure and clear appearance. The paragraphs should be concise and sentences easy to understand. In a good guide, the titles and subtitles are informative and encapsulate the contents of the following text. It is essential that the guide is written to the precise target audience selected. (Hyvärinen 2005.) Guides as a literature are portrayed as important to practical life (Jussila 2008, 23).

The guide to intraoperative monitoring entails the principles of monitoring a patient under general anesthesia and different variables affecting to it. The material promotes student education in the practice place and strives for maximizing the benefit and learning gained from anesthesia practice. Further, it seeks to aid nurse tutors in their mentoring task. This guide can be applied in student orientation and instruction in the anesthesia practice. The guide was designed in a way that it can be used as a teaching tool by nurse mentors. The project was started in spring 2013 when the permission for the guide from Central Finland Central Hospital was granted. Two contact persons from the hospital were assigned with whom I started communication on the project. Email was a chosen as the channel of communication for its convenience and easy use.

From a guide the reader seeks help, benefit, information, learning and skills to improve and develop themselves. For the writer of a guide is important to appreciate what the reader already knows. On one hand, the content of a guide should not be too basic and on the other hand not too specialized as to be overly difficult to grasp. The needs of the audience the guide is written for need to be investigated. (Rentola 2008, 92-93.) To write for the target audience, international nursing students in JAMK were asked what kind of guide they would benefit from. In addition, they were inquired what they

experienced difficult or hard to understand during their anesthesia practice. Their views impacted the guide and its contents.

Here are some of their comments in cursive writing:

*“For me the most difficult things were learning about the monitoring equipment like the [anesthesia] machine”*

*“The technology in use”*

*“The use of those many machines in the room. At least the basic knowledge”*

In the guide information on the functioning of the equipment and machines was incorporated. Short and concise explanations were tried to be given that still would help a student gain an understanding of the subject. The idea of the guide was to provide basic knowledge for the students and induce them to discuss with their mentors on the issues they want to learn more about.

*“ ..The language of communication between the mentor and the student. It is hard for international students who don't speak Finnish that well”*

To facilitate communication between students and mentors a picture appendix and wordlists were included. Appendices contain material that complements the main text (Mertanen 2008, 58). In the picture appendix there are photographs of equipment used in anesthesia labeled in English and in Finnish. The picture appendices can be used as a learning tool: the mentor can quickly point out the objects for which she does not have an English word. The student may look from the picture the Finnish equivalent for an object she only knows or remembers in English. As there are different kinds of learners, English-Finnish and Finnish-English word lists were put together. Both lists consist of anesthesia nursing related vocabulary in alphabetical order. Slightly different words than in the picture appendices were chosen for the lists. This way there more words for learning could be incorporated into the guide.

*“But also the other part comes in from the students themselves, once they know where they are going to do their practice they should also get ready theoretically.. the nurses have ended up assuming that the students know so much already”*

This notion encapsulates the purpose of creating the guide for international students to intraoperative monitoring in general anesthesia. The guide is to be present at the practice place when the student feels need for revision. When doing a practice, new issues and questions rise all the time. From the guide, students may find explanations to things that puzzle them. The guide also fits for student orientation at the beginning of practice. It can be used for self-study as well as a learning tool with the mentor. During the data collection a great variety of literature was read on the subject. Information was collected from both English and Finnish sources. Books, articles, guides, journals and web sites were used. The informative content complements the learning gained from school. In relation to publications of the subject such as textbooks, the contents are slightly simplified and condensed to fit the purposes of the guide.

The practical use of the written material creates the base for the visual appearance. The contents of the written material should be in line with the layout and visual style. (Hatva 2008, 79-81.) When planning the appearance of the guide, the color scheme of the hospital's logo namely blue, green, and orange was desired to be used. The visual look was to be fresh and appealing. Pictures encapsulate information in visual form. They help understanding the text and act as memory aids. The function of a picture in text can be documentative, orientational, and symbolic. (Op cit. 2008,86.) From the start use of pictures and photographs were decided to be used to make the guide illustrative and appealing. Further, the photographs included were meant as visual aid and teaching tools. Permission for photographing in the hospital's premises was granted for the purposes of the guide. The persons photographed gave their permission for the use of the photos. Good factual text is understandable, objective, and exact. It should inspire the reader and be uncomplicated to read and understand. (Hiidenmaa 2008, 63,71). To improve the readability the guide for the Central Finland Central

Hospital has references in the end page and not after every sentence as in the theory part of the thesis. The used language was aspired to be comprehensible and the words accessible for students. The table of contents makes search of information easier (Mertanen 2008, 59). For this purpose the contents page itemizes all the discussed topics. The user of the guide can find their topic of interest by quickly scanning through the table. In addition, sub chapters and shorter paragraphs are used for user convenience.

## **11.2 The Implementation and Evaluation of the Guide**

For the purposes of the Central Finland Central Hospital's paper-free policy, the Guide for International Students to Intraoperative Monitoring in General Anesthesia is published in electronic form. The guide is meant to be found and downloaded from the hospital's intra web. Students can alternatively read the guide in an electronic form or print it. To fit their learning targets, the guide may be printed as a whole or pages of it. To be reliable and adaptable to practice, guides need to be contemporary and the information in them updated (Jussila 2008, 25). For this purpose, permission to edit and update the contents was given to Central Finland Central Hospital. As an aspiration for reliability of the guide valid and up to date sources are strived to be used. The content of the guide is studied by the Central Finland Central Hospital before instalment to use. This in its turn aims at assuring the accuracy and ethicality of the guide. The thesis was assessed by the customer with the help of JAMK's host organization's assessment form. The choice of topic for the thesis was considered necessary and sought after by the representatives of the host organization. The usefulness of the material to nurse mentors was remarked on. The knowledge base of the guide was regarded satisfactory for the purposes of the material in student education. The visual look of the guide was deemed clear and easy to read. Thanks were given to the coherent and logical headings and use of forms, pictures, and photographs. The Guide for International Students to Intraoperative Monitoring in General Anesthesia was judged as a good compact package of general information of anesthesia nursing. With the opportunity to comment and ask for corrections and

improvements, no proposals for improvement were given to the author by the customer.

## **12 Discussion**

The aim of this bachelor's thesis was to increase the knowledge and skills of perioperative students practicing in the operating ward of the Central Finland Central Hospital. Another aim was facilitation of the work of nurses as student mentors. As a result the Guide for International Students to Intraoperative Monitoring in General Anesthesia was devised. Nursing perspective guided the planning, writing and implementation phases of the project. The project can be seen as successful and the customer expressed contentment for the product. The guide produced is adaptable to practical working life and student accessible. Challenging in this project was the defining and limiting of the exacting contents to a student friendly but still sufficiently extensive scope. The result was achieved by consultation of mentoring teachers and nursing students while planning and shaping the guide. A disadvantage of the produced material is the lack of feedback of the guide's functionality in practice. As the guide is in its initial implementation phase, this thesis is finalized. For further updates and amendments the material of the guide can be edited by the owner Central Finland Central Hospital.

The qualifications for registered nurses by the Finnish Nurses Association (2014) are demanding and wide-ranging. As a registered nurse in Finland one must have a great theoretical knowledge base of the field and be able to apply it to practical use. In addition to skills such as independent evidence based decision making and high degree of precision, nurse should aspire to develop the field and her own skills. This thesis has advanced the field of nursing by producing viable teaching and learning material for the use of professionals as well as students of the field in the Central Finland Central Hospital.

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## APPENDICES

# Intraoperative Monitoring in General Anesthesia



## a Guide to International Students

A Bachelor's Thesis in Nursing

2013

lita Niutanen

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## Introduction

This guide is a product of a work-development related thesis. It was produced as a project to Central Finland Central Hospital. The aim was to increase nursing student's understanding and knowledge of intraoperative care and nurse anesthetists' work. The purpose was to create an informative guide to international students practicing in the Central Finland Central Hospital. The interest for doing the guide to international students was the shortage of material in English on the subject in the local hospital. The subject the thesis is current and necessary as there are roughly 60 international students practicing in the Central Finland Central Hospital every year.

The guide to intraoperative monitoring entails the principles of monitoring a patient under general anesthesia and different variables affecting to it. The material promotes student education in the practice place and strives for maximizing the benefit and learning gained from anesthesia practice. This guide can be applied in student orientation and instruction in the anesthesia practice. The guide was designed in a way that it can be used as a learning tool by nurse mentors. The theoretical base of the thesis is on intraoperative nursing and anesthesiology.

Welcome to study!

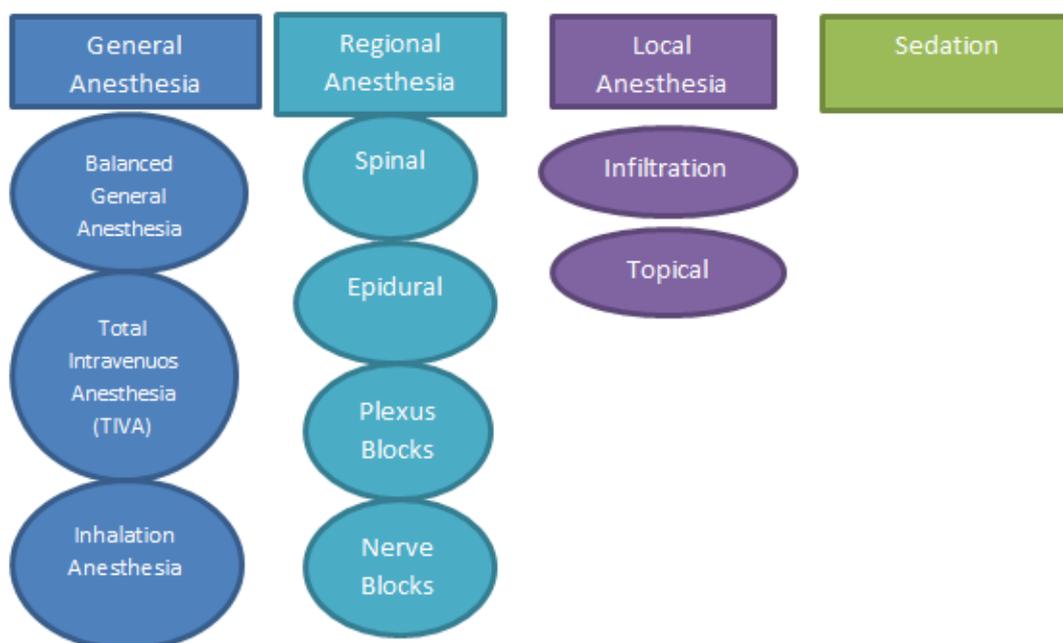


## 1 What is Anesthesia?

Anesthesia is a pharmacologically induced reversible state during which surgical procedures can be done to patient. Types of anesthesia can be categorized into general anesthesia, regional anesthesia, local anesthesia and sedation. These can also be combined to achieve a desired effect, emphasize a certain effect or minimize unwanted side effects. The choice of anesthesia type depends on several factors such as the length of surgery, the operated area, patient's age and general health and demands of the situation.

This guide concentrates on general anesthesia. General anesthesia is composed of sleep, lack of pain (analgesia), amnesia (no memory of from anesthesia), and sufficient muscle relaxation. This is achieved by administering anesthetic agents intravenously and/or anesthesia gases via mask. Unobstructed airway is secured with intubation tube or laryngeal mask. The air way maintenance device is used for the delivery of oxygen and anesthesia gases into and out of the patient. The anesthesia machine contains a ventilator that delivers the gases. Anesthesiologist is a doctor specialized in anesthesiology. She decides the anesthesia method, inducts anesthesia and terminates it. She is responsible for the patient's vital functions during surgery and orders administered drugs. Anesthesiologist is assisted by nurse anesthetist. Good anesthesia is conducted safely, ensures painlessness for the patient also post-operatively, and is quick to recover from.

### Types of Anesthesia



## 2 Intraoperative phase

Intraoperative phase begins at patient admission to the operating theater. The patient is prepared for the operation, anesthetized, monitored, and surgical operation is performed. Intraoperative care is systematic and well-planned team work. A team of doctors, surgeons, and nurses work in co-operation for the benefit of the patient's welfare. Intraoperative nursing activities center on facilitating the procedure, promoting patient safety, preventing infection, and monitoring and aiding the patient's physiological wellbeing. The intraoperative phase lasts until transferal to post anesthesia unit.

## 3 Nurse Anesthetist

In Finland, nurse anesthetist is a registered health care professional who works in the perioperative setting.

Nurse anesthetist operates in the Operating Room (OR), Post Anesthesia Care Unit (PACU), and in out chapters where anesthesia is required such as in radiology, magnetic resonance imaging, endoscopies, and electroconvulsive therapy.

During the entire perioperative phase the nurse anesthetist is responsible for ensuring her patient's holistic well-being and safety. The nurse anesthetist works in close co-operation with anesthesiologist. Together they form a team that administers, maintains, and ends anesthesia. Prior to operations, nurse anesthetist reserves and prepares the equipment needed. She must know how to operate the machines required in anesthesia monitoring and check their functioning. For each patient the nurse anesthetist collects patient data such as laboratory results and evaluates its relevance to anesthesia. During the intraoperative phase the nurse anesthetist is responsible for pharmacologic care, patient monitoring, and supporting vital functions. Her actions are in accordance with the anesthesiologist's care plan.



Administering and planning fluid therapy is one of the nurse anesthetists' duties. She has to have the knowledge and skills to perform blood transfusion therapy and conduct invasive monitoring. In addition, ability to know how to act in an emergency and resuscitate correctly is required. In regional and local anesthesia where the patient is awake the nurse anesthetist knows how to give information and guidance. It is a skill for the nurse anesthetists to know how and when to give emotional support.

When the patient is transferred to PACU or other care units the nurse anesthetist gives a report to ensure the continuity of the care. In the PACU nurse anesthetist monitors patients and gives post-operative care until the patients' condition allows transfer. The nurse anesthetist is familiar with different methods of pain management and is able to carry out them. In day surgery units, nurse anesthetist gives post-operative care guidance and discharges patients.

In all of the perioperative phases nurse anesthetist documents the performed interventions to the patient and other relevant issues. In her responsible work, the nurse anesthetist has to possess an extensive physiological and pharmacologic knowledge base to be proficient. Her actions should always be juridical and follow the ethical principles of nursing.

#### **4 Patient monitoring in general anesthesia**

*"Monitoring means looking at the patient" –World Health Organization.*

Patient monitoring has a central role in the intraoperative phase. Anesthesia and surgery impact the patient's physical functioning and predispose it to a risk. The anesthetic agents depress vital protective reflexes and render the patient unable to maintain respiratory function. A properly trained health care professional such as anesthesiologist or nurse anesthetist must all the time be in charge of supporting the vital functions of a patient under general anesthesia. It is a key principle in anesthesia that the patient is never left alone and unattended.

The monitoring of an anesthetized patient aims at prevention of complications, early recognition of imminent changes, and timely delivered care. The extent

of monitoring depends on several factors such as the patient's state of health and the anesthesia method used. In addition, the operation in question, its scale and duration significantly affect the monitoring. The patient should be observed before the induction of anesthesia to get start values. Later in surgery these can be used as a reference point to which changes are compared.

Finally, although a great variety of technical means of measuring vital functions exist, the traditional ways of ascertaining the patient's welfare should not be forgotten. Traditional clinical monitoring is direct observation of the patient for abnormal physiological events. This includes using the senses of hearing, touch, sight, and smell. Examples of clinical monitoring are auscultation by stethoscope of the correct placement of intubation tube, palpation of the pulse from the radial artery, feeling the chest for respiratory movements, touching the extremities for temperature, and looking at the pupils to evaluate the depth of anesthesia. Abnormal smells can be caused by leaking anesthetic gas. The nurse anesthetist should always have access to the patient and the monitors. The drapes should be arranged so that they provide a clear view of the patient and enable clinical monitoring.

#### **4. 1 Recommendations of Monitoring in Anesthesia**

The Finnish Society of Anaesthesiologists has produced guidelines for monitoring during anesthesia and surgery. The guidelines have been drafted as an effort to standardize patient monitoring and promote patient safety. Recommendations for monitoring in general anesthesia are divided in to the components of oxygenation, ventilation, circulation, temperature, muscle relaxation, concentration of anesthesia gases, and alarms. In the following table the recommendation for each component is represented. Clinical monitoring was included in all components.

#### **Recommendations for Monitoring in Anesthesia**

	Monitoring target	The Execution
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<p><b>Oxygenation</b></p>	<ul style="list-style-type: none"> <li>-Inhaled anesthesia gas concentration</li> <li>-Blood oxygen concentration</li> <li>-Tissue oxygenation</li> <li>-Changes in the oxygen consumption</li> </ul>	<ul style="list-style-type: none"> <li>-Measuring the oxygen concentration in the inhaled gases</li> <li>-Using Pulse Oximetry</li> <li>-Blood gas analysis as needed</li> <li>-Using monitors with alarms</li> </ul>
<p><b>Ventilation</b></p>	<ul style="list-style-type: none"> <li>-The carbon dioxide concentration in the exhaled air (etCo2)</li> <li>-Changes in the Co2 production</li> </ul>	<ul style="list-style-type: none"> <li>-Ensuring the correct placement of the intubation tube by auscultation</li> <li>- Constant measuring of etCo2</li> <li>-Following the inhaled Co2 in a machine with rebreathing system</li> <li>-Blood gas analysis as needed</li> </ul>
<p><b>Circulation</b></p>	<ul style="list-style-type: none"> <li>-Adequate circulation</li> </ul>	<ul style="list-style-type: none"> <li>-Blood pressure and pulse measurements at least in 5 minute intervals</li> <li>-Constant ECG measuring</li> <li>-Pulse Oximetry</li> <li>-Monitoring diuresis</li> <li>-Measuring peripheral temperature</li> <li>-Invasive blood pressure monitoring as needed</li> </ul>
<p><b>Temperature</b></p>	<ul style="list-style-type: none"> <li>-Maintaining optimal temperature</li> </ul>	<ul style="list-style-type: none"> <li>-Following the effect of used heating methods</li> <li>-When needed, invasive monitoring of core temperature</li> </ul>

<b>Muscle Relaxation</b>	-Optimal muscle relaxation needed for the operation  -Prompt recovery of muscle tonus	-Use of peripheral nerve stimulation
<b>Concentration of Anesthesia Gases</b>	-Optimal administration of anesthetic gases	-Measuring the concentration of anesthesia gases in inhalation and exhalation
<b>Alarms</b>	-Notice changes in vital functions	-Sound alarm for at least to the lower limits of apnea, minute ventilation, and inhaled oxygen concentration  -alarms for the lower limits of Spo2, Pulse, Blood pressure, and etCo2

## 4.2 Monitors

In general, a monitor is a machine that consists of the following components: a device attached or connected to patient, a measuring device that converts the detected information into an electrical signal, a computer that processes the signal, and a display showing the measured variable in a numeric form or a shape. Patient monitors enable more detailed observation of physiology.

However, there is a risk of misinformation and misinterpretation.

Understanding how the monitors work allows the user detect when the machine is not functioning properly or produces unreliable results. The nurse anesthetists and anesthesiologist form a crucial link between the machine and the patient.

Essential features in monitoring are the ability to interpret the machine-produced complex clinical data, recognize threatening changes, and take necessary measures to correct the situation.



### 4.2.1 Alarms

Monitors include alarms that by sound react to values over or under the set limits. The limits are part of the machine's basic functions and set by the manufacturer. Children and adult patients have their own alarm limits. The user of the monitoring set can also change the limits to suit for individual patients.

Alarms are important as they draw attention to developing physical changes and need to secure the patient's vital functions. It needs to be acknowledged, however, that the information given by a machine is open to interpretations and false readings do occur. Artifact from electrical interference such as surgical diathermy or movement triggers false alarms. The reason for an alarm, even a false one always has to be found out. The nurse anesthetist should monitor both the patient and the machine, make comparisons, and form a holistic understanding of the situation.

## 5 Circulation

The cardiovascular system consists of the heart, the blood and the blood vessels. Heart is a muscular pump that must constantly push blood into the vessels to deliver oxygen and nutrients to the cells. The heart's left side pumps oxygen-rich blood from the lungs to the systemic circulation. After unloading O<sub>2</sub> and nutrients, the blood then picks up waste products such as carbon dioxide (CO<sub>2</sub>) and delivers them back to the right atrium. The right side of the heart takes the blood from systemic circulation to pulmonary circulation. In the lung's capillaries the unloaded CO<sub>2</sub> is exhaled and inhaled O<sub>2</sub> collected. The freshly oxygenated blood then travels again to the left atrium.

The principle aim in anesthesia monitoring is to ensure oxygen delivery to the tissues. It is necessary to monitor the patient's circulation during anesthesia as the anesthetics and surgery change hemodynamics. Cardiac function during anesthesia is evaluated by different blood pressure monitoring techniques, studying the pulse, using oxygen saturation meter, checking peripheral perfusion, and following the breathed out CO<sub>2</sub> values.

### 5.1 ECG (Electrocardiography)

ECG records the heart's electrical current as the heart muscle fibers produce action potentials with each heartbeat. In brief, ECG can be said to describe the electrical function of the heart. ECG is a standard monitoring procedure for each patient. The purpose of ECG is to observe the heart's function, detect cardiac problems, arrhythmias, ischemic changes or other deviations. In normal surgical conditions, three leads are placed on the patient: **red** on the right side, second intercostal space on the sternum, **yellow** on the left side correspondingly, and **green** on left side. The electrodes should be connected to the patient before the induction of anesthesia to give a reference point for the future readings. A visual representation of the heart's function can be seen on the monitor's screen. The waves in a normal sinus rhythm are P, Q, R, S, and T. The machine detects deviations in the ST levels and alerts the user; elevation or depression in the ST point to ischemic changes in the heart muscle. It should be remembered that ECG use is restricted to the electrical function of the heart; it does not tell about the mechanical function and cannot assess the cardiac output or blood pressure. ECG can also produce artifact, a false interpretation resulting from interference to the signal. The reason for artifact can be a moving patient, displaced electrode or the use of surgical diathermy. The pulse figures given by ECG should be compared to the pulse oximetry's readings.



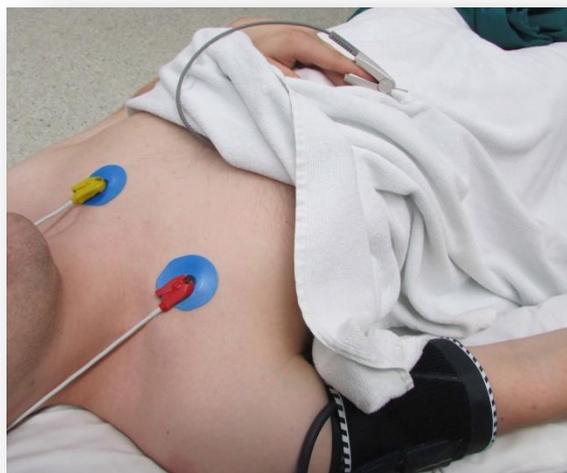
ECG from a monitor

## 5.2 Blood Pressure

Blood pressure is the force blood exerts on the walls of blood vessels with every heartbeat. Systolic blood pressure tells the highest pressure in the arteries when the heart contracts. Diastolic blood pressure is the lowest pressure in the arteries when the heart is at rest between contractions. Blood pressure is controlled by several interconnecting negative feedback systems such as the cardiovascular center in the brain's medulla oblongata, baroreceptors and chemoreceptors in the aorta and carotid arteries, and hormonal regulation. These systems adjust to changes in blood pressure by regulating the heart rate, stroke volume, blood volume, and vascular resistance.

### 5.2.1 Non-invasive Blood Pressure (NIBP)

In the operating room automated oscillometer (blood pressure measuring device) is used. The cuff is attached on the left arm if possible and the hand placed at heart level. The cuff is typically automated to inflate in 5 minute intervals. Additional measurements are made as necessary. Correct cuff size ensures reliable measuring



results. Too small cuff distorts the results upwards resulting to interpretation of high blood pressure. Too large cuff cannot achieve necessary pressure resulting to false low measurements. Changes of surgical position reflect to changes in blood pressure. Baseline blood pressure value is needed for determination of hypo- or hypertension. Measurements taken before the induction of anesthesia and administration of drugs provide crucial information on hemodynamics prior to affecting surgical variables. The limit values of low or high blood pressure are individual. Consequently, the alarm limits are accustomed for each individual patient.

Intraoperative hypotension is caused by anesthetics that induce vasodilation and consequently lower blood pressure. Other reasons for hypotension during surgery can be loss of blood and resulting hypovolemia, dehydration, low cardiac output or vascular resistance. Also multiple trauma, burns, and shock cause considerable hypotension. Limits for hypotension depend on clinical findings such as the level of consciousness, diuresis, and potential cardiac ischemia. As a rule, generally healthy people endure lower blood pressure better than people with multiple illnesses and those suffering from cardiac conditions. Normally hypertensive patients can manifest clinical findings related to lowered blood pressure with blood pressure values considered as regular. In general, intraoperative hypotension can be defined as a 20% decrease in systolic blood pressure from the baseline value. Hypotension is managed by temporarily increasing the flow of i.v fluids and giving a bolus of

antihypertensives such as etilefrine (Effortil ©) or Phenylephrine (Neosynephrine ©). Hypertension during anesthesia can result from pain, inadequate level of anesthesia, hypoxia or hypercarbia (raised amount of CO<sub>2</sub> in the blood). To correct the homeostatic imbalance, the patient is alternatively given more analgesics, the anesthesia is deepened, or the ventilation corrected.

Under anesthesia, fluctuation in blood pressure also reflects the depth of anesthesia in relation to the response to surgical stimulation. Disadvantages of non-invasive blood pressure measuring are inaccuracy during arrhythmias and inability to have continuous measurement.

### 5.2.2 Mean Arterial Pressure (MAP)

MAP is the average blood pressure in the entire cardiac cycle. It also represents perfusion pressure (the pressure that is needed for tissue and organ perfusion and cellular oxygenation). Adequate MAP ensures circulation and perfusion of the brain tissue. With hypotensive patients MAP provides better indication of perfusion than diastolic or systolic pressures. MAP is calculated by a formula of diastolic BP + 1/3(systolic BP – diastolic BP). Anesthesiologist may give a target MAP as a goal-directive therapy. This helps the anesthesia nurse to respond pharmacologically to support the patient's vital functions. A typical MAP limit is 60-70.

## 5.3 Invasive Blood Pressure Monitoring

Invasive methods of measuring blood pressure are used when information of the patient's circulation is needed in real time. In general these are high risk anesthesia patients, patients with cardiovascular diseases or trauma, and patients who have multiple chronic conditions.

### 5.3.1 Arterial Pressure

In order to measure arterial pressure, an artery is cannulated. Commonly the radial artery is used. To prevent blockage, a heparinized saline drips through the transducer (a device that



Arterial Pressure Measuring Device

changes liquid's movement to an electrical signal) flushing it. One advantage of the arterial cannula is the possibility to draw blood samples for arterial blood gas analysis or other use. The use of the arterial cannula is a common practice with severely ill patients both intraoperatively and in the intensive care unit. The risks of arterial pressure monitoring include infection, hematoma and bleeding, thrombosis and nerve damage. False readings may be due to equipment misuse; the catheter is kinked, the transducer is placed at an incorrect level or is calibrated incorrectly.

### **5.3.2 Central Venous Pressure (CVP)**

Central venous pressure is measured by catheterizing a vein leading directly to the heart. Usually the subclavian or jugular vein is used. This catheter is called central venous catheter or CVC in short. Central venous pressure is used to estimate the pressure in the right atrium to where the blood returns from the systematic circulation. In short, CVP predicts the function of the heart's right side but also gives indications of blood volume, venous return, and intrathoracic pressure. CVP levels can be used in the planning of fluid and electrolyte balance.

### **5.3.3 Pulmonary Artery Pressure (PAP)**

To measure the pressure inside pulmonary artery, a catheter a catheter called Swan-Ganz is inserted into the vena cava and from there fed into the pulmonary artery. The pulmonary artery catheter is often used for critically ill patients when constant feedback of hemodynamics is needed and less invasive means are excluded. Some of the risks of measuring PAP are complications related to the insertion, ventricular arrhythmias, and displaced or knotted catheters.

## **5.4 Pulse**

Pulse is the traveling pressure wave after each contraction of the heart's left ventricle; the arteries expand and then recoil. The pulse is best palpated in arteries near the surface of the body. These are for example the radial and the carotid artery. At rest the pulse rate normally varies from 70 to 80 beats per minute. Tachycardia means rapid resting pulse or pulse exceeds 100 beats per minute. Bradycardia is pulse rate of 50 beats or less per minute or slow resting pulse. Heart rate is the amount the heart beats in a time unit, usually a minute and marked as bpm (beats per minute). Pulse and heart rate are often

used as synonyms. In the operating theater variations in pulse between individuals result from age, physiological factors, and the method of anesthesia. A rise in the pulse can indicate too light anesthesia or inadequate analgesia meaning that the patient feels pain. Other reasons include less carbon dioxide exiting the patient, loss in blood volume and raised body temperature (fever). Falling pulse may be an indication of too deep anesthesia or a late stage of considerable hemorrhage.

## 6 Respiration

The body's cells need continually oxygen for metabolic reactions. These reactions produce a waste product called carbon dioxide. The respiratory system exchanges these two gases by supplying air and eliminating  $\text{CO}_2$ . The cardiovascular system participates in the transportation of the gases from the lungs to the tissues and back.

During general anesthesia, the most important object of monitoring is respiration. The anesthetic agents cause respiratory depression and muscle relaxants the loss of respiratory muscle tonus. The airway must be secured and maintained by an artificial airway management device, most commonly intubation tube or laryngeal mask (LMA). The breathing function is wholly or partially performed by a machine that delivers oxygen and anesthetic gases; from exhalation the machine collects and removes carbon dioxide. The direction of the gas flow is controlled with unidirectional valves. In the commonly used circle system the gases are



The Anesthesia Machine

circled and rebreathed in part. The security of breathing system needs to be monitored during operations and checked before every use.

Attaching the patient to ventilator does not remove the responsibility of monitoring the machine. The respiratory function needs to be monitored constantly by observing the patient and processing information from the displays. Monitoring of respiration can be divided in to the observation of the gas exchange and ventilation. In addition, the airway pressure and gas concentrations are observed. These are discussed in the following chapters.

## 6.1 Gas Exchange

The purpose of monitoring gas exchange is to ensure adequate ventilation and the oxygenation of tissues. Oxygenation is measured by oxygen saturation and ventilation evaluated by the amount of expired carbon dioxide.

### 6.1.1 Oxygen Saturation (SpO<sub>2</sub>)

The oxygen in blood is stored in haemoglobin. The binding of oxygen to haemoglobin is called oxygen saturation: the haemoglobin molecule is saturated with oxygen molecules. Oxygen saturation is measured with a pulse oximeter and represented in percentages.

Measuring oxygen saturation is a standard anesthesia practice as it gives constant information in a non-invasive way of cardio-pulmonary function, tissue perfusion and registers the pulse.

The oximeter is attached to the tip of a finger, earlobe or nose. During anesthesia

SpO<sub>2</sub> should measure between 95-100%. Saturation percentage of 92 or under is considered hypoxia, inadequate concentration of oxygen in the blood and disrupted tissue perfusion. Clinically, a patient with good perfusion has pink lips and tongue. Hypoxia is shown by pale, even bluish coloring. Visual detection of hypoxia is more difficult in dark skinned patients. The pulse oximeter requires good peripheral pulse waveform for detection. This may cause a problem with patients who have poor peripheral perfusion. In addition, nail polish and synthetic nails interfere the signal and may give false readings.



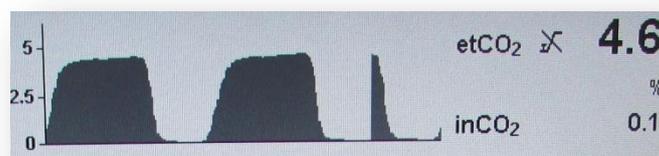
The Pulse Oximeter

If possible, the oximeter should be placed on a different arm from the blood pressure cuff. The inflating cuff temporarily blocks the circulation on the arm and the oximeter registers artifact.

### 6.1.2 End-Tidal Co2 (etCo2)

Ventilation means the body's ability to remove carbon dioxide, the waste product of respiration. Carbon dioxide is then a prominent regulator of respiration. The adequacy of ventilation is assessed by measuring the carbon dioxide concentration of the exhaled air. This value is shortened as etCo2.

Capnography attached to the breathing tube analyzes the carbon dioxide from the breathed air. The capnograph draws a curve where the exhalation is seen as a wave-like form and the inhalation as a flat zeroing line. One curve represents one respiratory cycle. In normoventilation etCo2 is between 4,5 and 5,5.



In addition, the amount of inflowing co2 (FiCo2) is followed to prevent in the accumulation of carbon dioxide in the blood stream. The absorbers that removes co2 from the exhaled gas should be removed no later than when the FiCo2 value is 0,5%.

## 6.2 Ventilation

Pulmonary ventilation is the exchange of oxygen between the atmosphere and the lung alveoli. This is achieved with the alternative contraction and relaxation of the respiratory muscles and the resulting pressure differences. The rate of inhaled oxygen and the breathing work required from the lungs are influenced by the lung compliance and airway resistance.

### 6.2.1 Respiration Frequency (RF)

A basic measure of respiratory function is the respiration frequency, also called respiratory rate. The respiratory rate is monitored to recognize pulmonary insufficiency and apnea. The respiratory rate announces the amount of breaths taken in a minute. This can be calculated either by feeling the chest movements or from the capnograph readings. For adults, in normoventilation

Heng. 11

RF in a monitor display

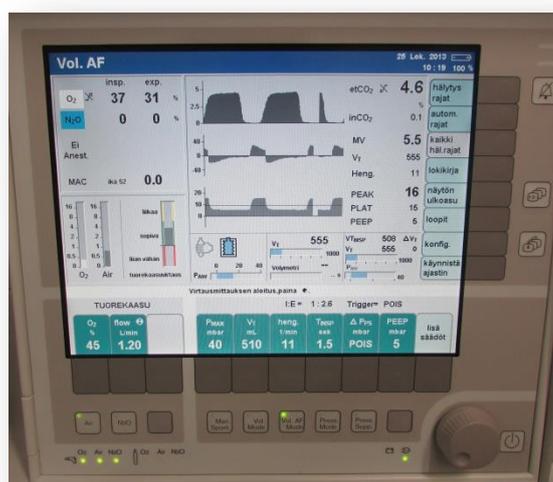
respiration frequency is 10-20 per minute. Increased respiratory rate tells of greater breathing effort and possible disruption of gas exchange.

### 6.2.2 Tidal Volume (TV)

Tidal volume (TV) measures the amount of gas delivered into the lungs in one breath. In an average sized adult TV is 500 ml. With an intubated patient the amount of inflowing and out coming gases needs to be monitored to ensure adequate ventilation and prevent hypoxia.

### 6.2.3 Minute Volume (MV)

Minute volume (MV) describes the amount of gases the patient breathes in a minute. MV is measured as millilitres per minute. The ventilator settings are regulated on the basis of either TV or MV measures.



Ventilator monitor's display

## 6.3 Airway Pressure

Airway pressure is the amount of work the lungs need to do in order to deliver a breath. Airway pressure monitoring is needed on one hand to avoid lung trauma from excessive pressure; and on the other hand to ascertain that a necessary amount of pressure stays in the lungs preventing the alveoli from collapsing. A pressure monitor is incorporated into the ventilator. In average, airway pressure ranges between 10-25 cmH<sub>2</sub>. The size of the intubation tube in relation to the set gas volume values affects the pressure. Pressure changes during anesthesia can result from obstruction in the airways or leakage from the breathing system connectors. In addition, secretions in the airways, decreased lung compliance, and raised intrathoracic pressure increase the respiratory work. The values PEAK, PLAT, and PEEP are used to describe the prevailing airway pressures.

### 6.3.1 PEAK

Peak Inspiratory Pressure is the maximum pressure in a single ventilator delivered breath.

### 6.3.2 PLAT

Plateau Pressure is the pressure in the lungs at the end inspiration when there is no active gas flow from the machine.

### 6.3.3 PEEP

PEEP is shortened from Positive End-Expiratory Pressure. In anesthesia PEEP is used to prevent atelectasis, the collapse of the lung alveoli. Atelectasis during anesthesia may be caused by decreased respiratory muscle tone due to the administered drugs. The positioning of the patient can be another factor. For instance, when the patient lies supine on the operating table the intrathoracic pressure increases and the airways are compressed. By applying PEEP, the alveoli are held open at the end-expiration preventing the total collapse of the lungs. In practice this means mechanically keeping positive pressure in the lungs by adjusting desired values to the anesthesia machine. PEEP increases lung compliance and prevents impaired gas exchange. Indications for the use of PEEP are obesity and lung disease.

## 6.4 Concentration of Gases

Inhalation anesthetics come in liquid form. Vaporizer is the part of anesthesia machine that vaporizes the inhalation anesthetics and conveys them in appropriate concentrations to the patient. The machine's flow meter can distinguish and measure the concentrations of not only the inhalation anesthetics but the administered oxygen, nitrous oxide, and carbon dioxide. The concentrations are presented in percentages. The gas concentration is monitored to maintain the desired depth of anesthesia and avoid too light anesthesia. By following the oxygen concentration, the delivery of air into the patient is ensured and hypoxia prevented.

## 6.5 Clinical Monitoring of Respiration

For safe anesthesia, respiration monitoring is complemented by clinical studying of the patient. The respiratory movements are observed to ensure that the airway remains open. The motion of the chest should be symmetrical and regular. The intubation tube has to be fixed securely to prevent its displacement. The pressure in the tube's cuff needs to be checked regularly



Cuff pressure meter

with a cuff pressure meter. Overinflated cuff can cause airway obstruction and underinflated one does not seal the trachea effectively. Respiratory sounds should resonate clean and clear. Both sides of the lungs ought to be auscultated by stethoscope. Signs of hypoxemia can be seen from the skin, lips, and nails. However, cyanosis is visible not until the oxygen saturation drops to under 80%. Ruddy complexion instead can be a mark of increased blood carbon dioxide. Formation of vapor in the intubation tube is a mark that oxygen indeed flows into the lungs.

## 10 Fluid Balance

The aim of fluid therapy during anesthesia is to maintain adequate circulating blood volume, renal function, oxygen delivery to tissues and electrolyte balance. Basic daily needs, too, need to be covered. This is achieved by replacing already existent losses and providing maintenance fluids.

During the intraoperative care patients lose fluid due to hemorrhage, losses to the third space and dehydration. Dehydration results from fluid loss by vaporization from the skin, the lungs, and the operated area as well as preoperative fasting. Most commonly administered fluids during the intraoperative phase can be categorized into basic and replacement fluids. Basic fluids include 5-10% glucose with or without a sodium and potassium addition. Anesthesia and surgical trauma cause metabolic changes in the insulin regulation which raise the blood glucose levels. If a glucose based replacement fluid is used, blood sugar levels can raise to exceed 10 mmol/l. Thus, glucose infusion is mainly used for the prevention of hypoglycemia in diabetic patients. Replacement fluids resemble by their electrolyte consistency the body's own fluids; these are Ringer-Acetate<sup>®</sup> and physiological NaCl. For minor blood loss a crystalloid electrolyte solution such as Ringer-Acetate<sup>®</sup> is used as a replacement fluid. Major blood losses are replaced with



transfused units of red cells.

When planning fluid therapy, several factors need to be taken into account. The basic fluid need of an adult is 2ml/kg/hour. Additional needs total 4-10ml/kg/hour on average depending on the amount of lost fluid. Potential losses due to diarrhea, vomiting and fever should also be considered. The age, size and medical conditions of the patient also affect fluid therapy. Fluid balance is monitored by examining blood pressure, pulse rate, respiratory rate and urine output. Losses to other catheters or drains should also be taken into account. Blood gas analysis taken from arterial blood provides valuable information on the acid-base balance, respiratory function, and the metabolic state. Electrolyte and fluid imbalances are corrected by adjusting the fluid therapy.

### Daily Fluid and Electrolyte Requirements of an Adult

Water	30-50 ml/kg
Glucose	1-1,5 g/kg
Sodium	1-2 mmol/kg
Potassium	0,5-1,5 mmol/kg
Magnesium	0,15 mmol/kg
Calcium	0,15 mmol/kg
Phosphate	0,3 mmol/kg
Chloride	1-2 mmol/kg

#### 10.1 Pulmonary Capillary Wedge Pressure (PCWP)

Maintaining functional blood capacity in the heart supports the body's ability to cope with the surgical stress. The blood capacity is perceived with filling pressure and end-diastolic pressure. The pressure in the pulmonary artery is created by the capillary circulation in the pulmonary arteries and the pressure prevailing in the left atrium. Pulmonary artery catheterization is commonly used for critically ill patients with cardiac complications. It enables monitoring the function of the heart's left side and helps detect left atrium failure.

Response to fluid therapy can rapidly be detected from the measured values. PCWP reflects filling pressure of the left atrium. Measuring PCWP is an invasive procedure. The pulmonary artery is cathetered with a balloon-tipped

multi-lumen Swan-Ganz's catheter. A balloon at the end of the catheter is inflated, wedging it into a hold inside the artery.

## 7 Depth of Anesthesia

Depth of anesthesia is a compound of hypnosis, antinociception, suppression of reflexes, and amnesia. Due to its nature, anesthesia depth monitoring requires an indirect parameter. The focus of the monitoring is on the level of hypnosis. Clinical signs of inadequate depth of anesthesia are raised blood pressure level, increased heart rate, and lacrimation. However, these alone are insufficient parameters. Using monitors that estimate the rate of awareness has been shown to reduce intraoperative drug use, speed recovery from anesthesia, and prevent complications such as postoperative nausea and vomiting.

### 7.1 EEG

Electroencephalography or EEG is used in the evaluation of the hypnotic component of anesthesia. EEG records the electrical activity of the cerebral cortex via scalp-attached electrodes.

#### 7.1.1 BIS

Bispectral Index Monitor or BIS is an EEG based monitor. Four electrodes applied to the forehead register EEG signal. BIS values range from 0-100, 100

indicating a totally awake and orientated patient and 0 a deeply anesthetized one. Adequate depth of anesthesia for surgical operation is between BIS 40-60. Although BIS is considered a fairly reliable meter in the operating theater conditions, different anesthetics, hypoxemia, and status epilepticus may interfere the readings.



BIS electrodes

### 7.2 MAC

MAC is shortened from minimum alveolar concentration. MAC of inhaled anesthesia gases is 1 when 50% of subjects do not produce reflex response to surgical incision. MAC is used as an indicator of satisfactory concentration of inhaled anesthetics to produce the wanted depth of anesthesia.

## 8 Pain

Patients have both juridical and ethical right to good pain management. The principle is that the patient should be as free of pain as possible. As there is no machine to monitor pain, vital signs and the patient's outer physical signals need to be inspected. Raised blood pressure and pulse can tell of experienced pain. Clinical signs include sweating, lacrimation, and creased forehead.

Anesthesiologist plans the drug therapy. He takes into consideration the surgery in question and patient's overall condition, not forgetting the individual factors such as age, weight, and possible allergies. In intraoperative drug therapy forethought and anticipation is needed. Patient should be given analgesic before pain is felt. This calls for regular pharmacologic intervention. Adequate dosing is necessary to ensure lack of pain. Response to the therapy should be monitored from the vitals.



In general anesthesia strong opioids such as fentanyl or remifentanyl are used intravenously. These analgesics produce strong but short effect which is why they need to be given regularly. Remifentanyl (Ultiva©) is normally given as an infusion while fentanyl (Fentanyl©) usually in boluses. Analgesics can be also administered to the epidural space via a preoperatively placed catheter. Local anesthesia techniques complement the pain treatment. They as well as the epidural catheter help in the postoperative care. Good pain management not only spares the patient from unpleasant feeling but also reduces the burden to cardiovascular system, expedites recovery, and reduces postoperative complications.

## 9 Muscle Relaxation

The level of muscle relaxation is monitored to optimize the time for intubation, to determine necessity for medication, and estimate recovery from the administered muscle relaxant.

The muscle relaxation agents (cisatracurium Nimbex©, rocuronium Esmeron©, suxamethonium Sukolin©) given in anesthesia inhibit the progress of electrical action potentials to the muscle fibers. Muscle relaxation monitoring is based on electrical stimulation of peripheral nerves and the received muscle response. In nerve stimulation a stimulus up to 70 mA is given to a motoric nerve and the associated muscular response is monitored. Usually the ulnar nerve is used and the response can be seen in the adductor muscle of the thumb. The current is given transcutaneously with applied ECG electrodes. Neuromuscular transmission monitor or m-NMT is the module used in measuring the effect of neuromuscular blockers.



NMT

### 9.1 TOF

TOF stands for train-of-four, a quantitative stimulation method where four stimuli of equal strength are given to a motor nerve in a sequence. If the muscle relaxation is total there is no muscle response. With the effect of pharmacological muscle relaxant fading, responses in the form of muscle twitches begin to appear. Finally, as the relaxation is over all four stimuli receive response.

## 11 Temperature

It is recommended that the patient's temperature is monitored in all surgical procedures lasting longer than 30 minutes. Both core and peripheral temperatures should be measured.

The body's normal core temperature ranges from 36 to 37 °C. In the peripheries the temperature is 2-4°C lower than in the core and the skin is

ever cooler. In normal conditions a 0,5-1 °C variation in the core temperature triggers physiological responses to regain the balance. In hypothermia this means peripheral vasoconstriction and shivering and in hyperthermia dilation of blood vessels and sweating.

Due to anesthesia the body's ability to regulate the core temperature is delayed and decreased. According to different sources 50-90% of patients suffer from perioperative hypothermia. Hypothermia predisposes the patient to infections and cardiac problems. Surgical wound healing slows down and unwanted changes occur in blood coagulation, blood viscosity, and platelet function. In addition, the time the body takes to metabolize and secrete drugs lengthens which results in longer hospital stays.

Measuring core temperature is always an invasive procedure. Temperature can be taken from the pulmonary artery, esophagus, nasopharynx, and urinary bladder. Temperature from the pulmonary artery indicates the temperature of the circulating blood. Thermometer in the lower part of esophagus measures the temperature of the heart and monitoring temperature from the



Hotline Fluid Warmer

nasopharynx reflects the temperature of the brain. Urinary bladder is also used as a core temperature measurement place but is susceptible to diuresis. A common place of measuring is the auditory canal.

Intraoperative thermal management is conducted by using heaters, thermal mattresses, infusions and fluids warmed to 37 °C, and thermal suits.

## 12 Diuresis

Diuresis, the excretion of urine is monitored in surgical patients to estimate fluid balance, hemodynamic stability, and kidney function. Urine output is measured and documented cumulatively. This provides information of hourly urine output as well as the total amount of excretion. Hourly urine output of 0,5-1ml/kg is considered a norm.

During the intraoperative phase reduced diuresis can result from circulatory, cardiac or hormonal changes. More rarely the cause is renal damage. Increased output of urine instead tells about heavy osmolar load. Indications for diuresis monitoring are urological, cardiologic, neurological, and vascular operations or other extensive procedure. In addition, time consuming surgeries, hypovolemia, acute kidney failure, heart failure, prolonged state of hypotension, and shock are causes for monitoring the urine excretion. In smaller surgical operations patients are not catheterized; instead, preoperatively bladder function is estimated by asking the patient.

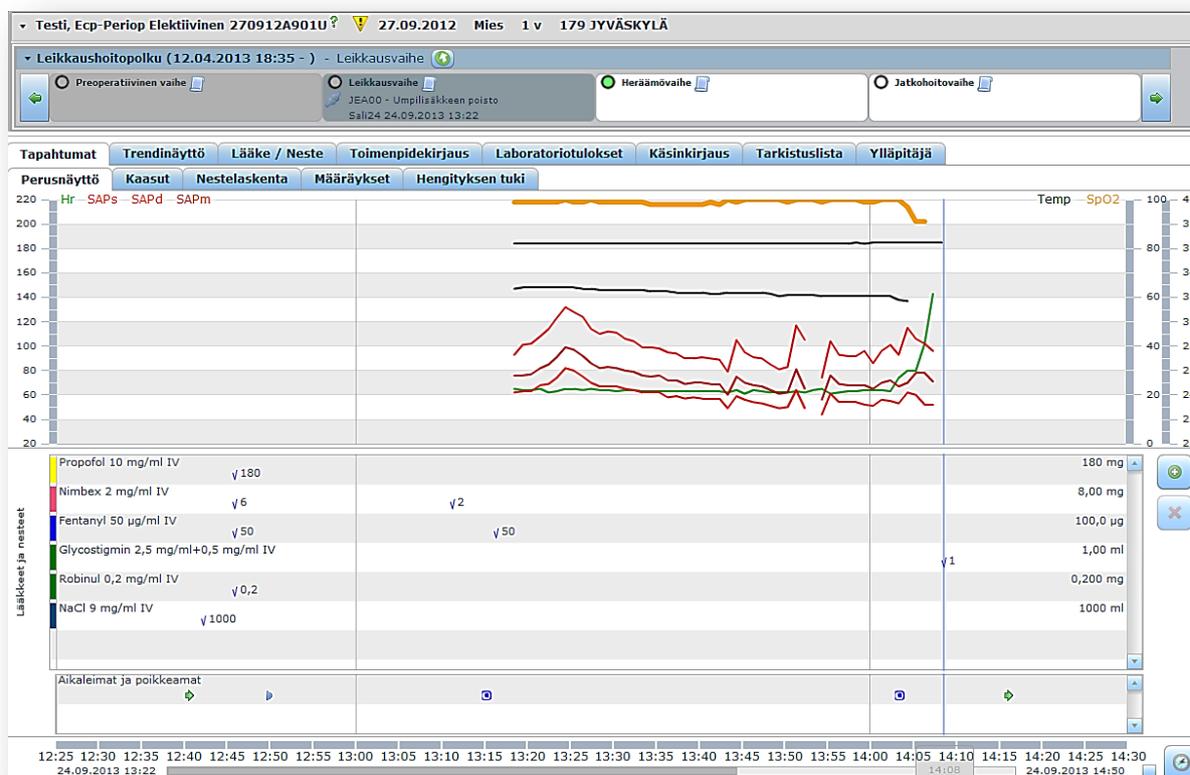
### **13 Position**

The aim of patient positioning in surgery is to provide optimal access to operate for the surgeon while protecting the patient from potential risks. Safe positioning requires good communication and co-operation between the surgeon, anesthetist, and nurses. In the beginning and end of the operation there needs to be enough helping hands when the unconscious patient is positioned or moved. Knowledge of physiological changes caused by a surgical position helps the planning and prevention of injury to the patient. Individual factors such as weight and height, illnesses, physical movement restrictions, and prostheses have to be debated in the planning.

Patient under anesthesia is susceptible to indirect trauma caused by inconvenient surgical position. These include injury to nerves, soft tissue, and muscles as well as pressure sores. Shearing of the skin and vascular problems may result from improper positioning. Nurse anesthetist has to pay attention to the placement of the intubation tube, infusion lines, catheters and other equipment attached to the patient. The position of the patient has to be regularly checked and changed when necessary. In long surgeries the head and extremities should be moved or their place shifted to prevent injury, pain, and numbness.

### **14 Documentation**

Patient documents are juridical records. The purpose of documentation is to ensure the safety and continuity of care. During the intraoperative phase an electronic anesthesia form is used. In Central Finland Central Hospital the data system in use is called Leija. Manual forms of documentation exist in case of technical failures. The machines used in monitoring automatically save data and log it into recording systems. The nurse anesthetist registers administered drugs, fluid therapy and diuresis in the form. In addition, possible blood sugar measurements taken during anesthesia are marked. Other anesthesia related factors that need to be entered to the recording system are the form of anesthesia and used equipment such as the size of laryngeal mask. At the end of the surgical procedure, the nurse anesthetist takes instructions for follow-up treatment from the surgeon and marks the amount of hemorrhage to the documentation system. It is important to have documentation of complications in the anesthesia that detail the incident. These need to be taken not only as a legal responsibility to do so but so that in future precaution can be taken.

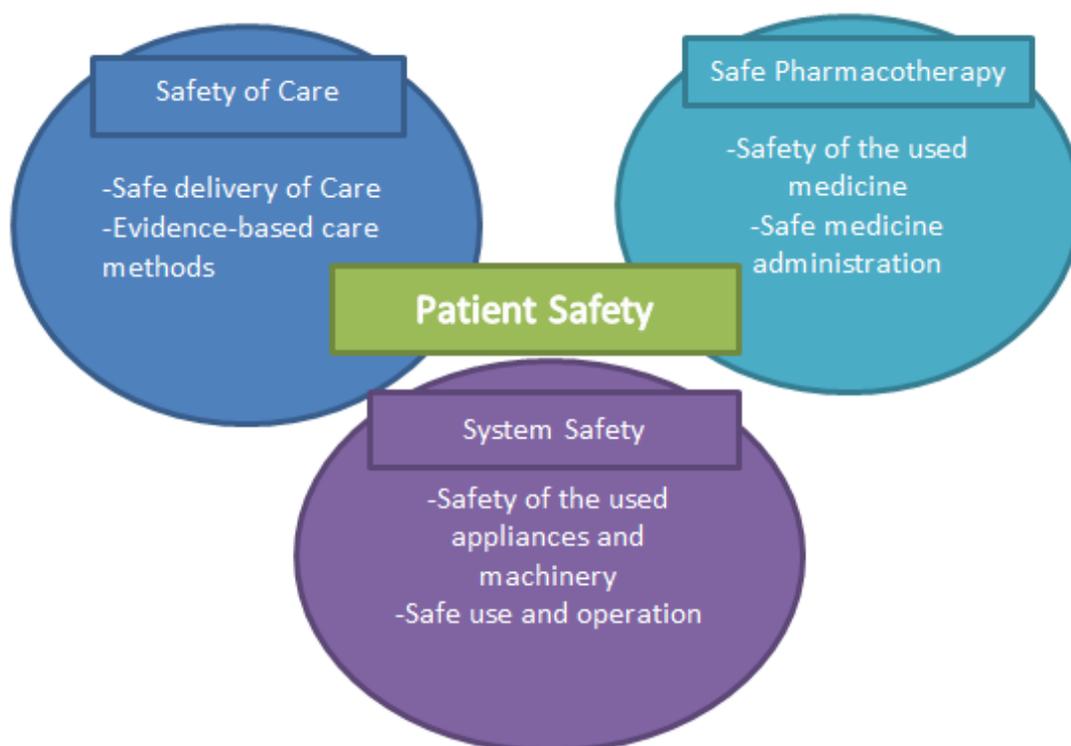


The electronic recording program LEIJA

## 16 Patient Safety

Patient safety is in a central role in all areas of health care. In practice, patient safety is all those actions and principles taken to protect the patient from harm and deliver safe care. It is composed of safety of care, safe pharmacotherapy, and system safety

### *Patient Safety*



Most risk situations could be prevented. Stumbling blocks are inadequacy or lack of communication, interrupted flow of information, and hurry. The consequences of compromised patient safety result to longer hospital stays and greater expenses to the national health care. This is without mentioning the harm to the patient and their next of kins. The importance of anticipating risky situations cannot be stressed. Safety incidents are reported to the web-based HaiPro system. The reporting is confidential and does not seek to blame or discipline. Rather, the purpose is to learn from mistakes by processing and evaluating the situations. Knowing what went wrong and why helps to avoid similar incidents occurring in future.

### 16.1 Patient Safety in Anesthesia Practices

During anesthesia patient is administered strong and fast-acting drugs intravenously. This always includes the risk of life threatening complications. Taking care of the physical safety, the nurse anesthetist never leaves his patient alone. Systematic operating and routine actions are adopted to all anesthesia practices to avoid accidents from occurring. The nurse anesthetist always does



Labelled syringe in infusion pump

his routine in the same way and same order from the equipment checks to anesthesia preparations. In this way he ensures that no safety step is neglected. The safety steps include among other things testing the function of the laryngoscope, suction, intubation tube's cuff, and anesthesia machine. Commonly occurring mistakes are medication related ones. To take preventive steps all syringes are marked with a named label that includes the strength of the active ingredient. An unknown syringe without a label invariably goes to pharmaceutical waste. When a drug is diluted or added to an infusion bag, a label providing information on the contents, amounts, patient's name, and the name of the adding person is filled and attached to the bag. A useful and effective tool in providing safe care is the surgical checklist recommended by the World Health Organization.



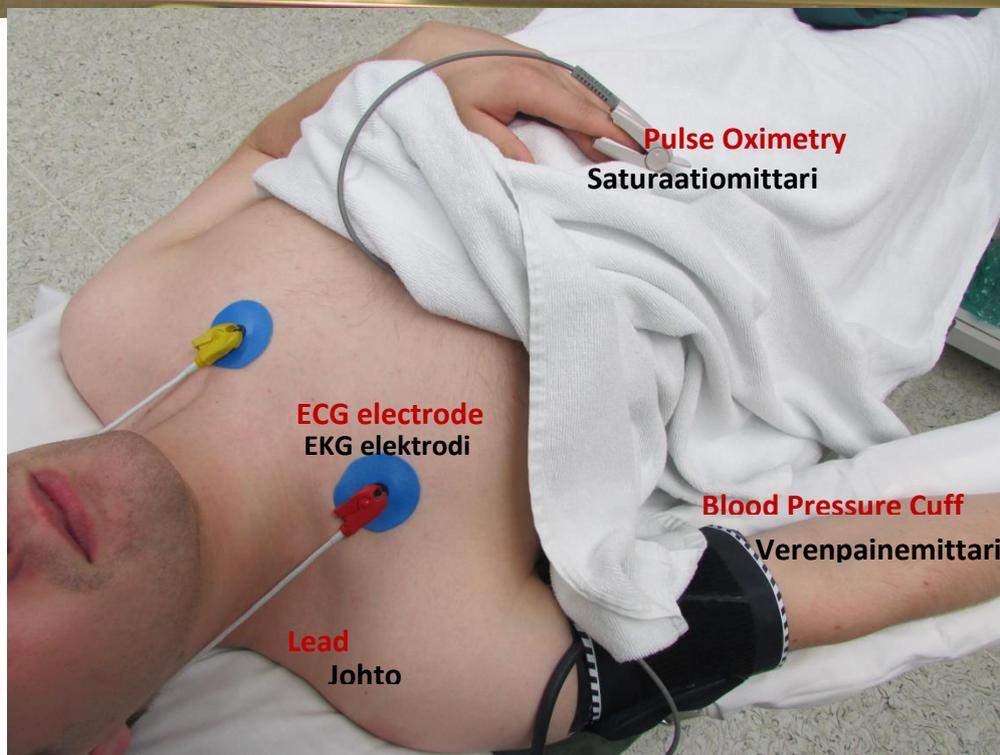
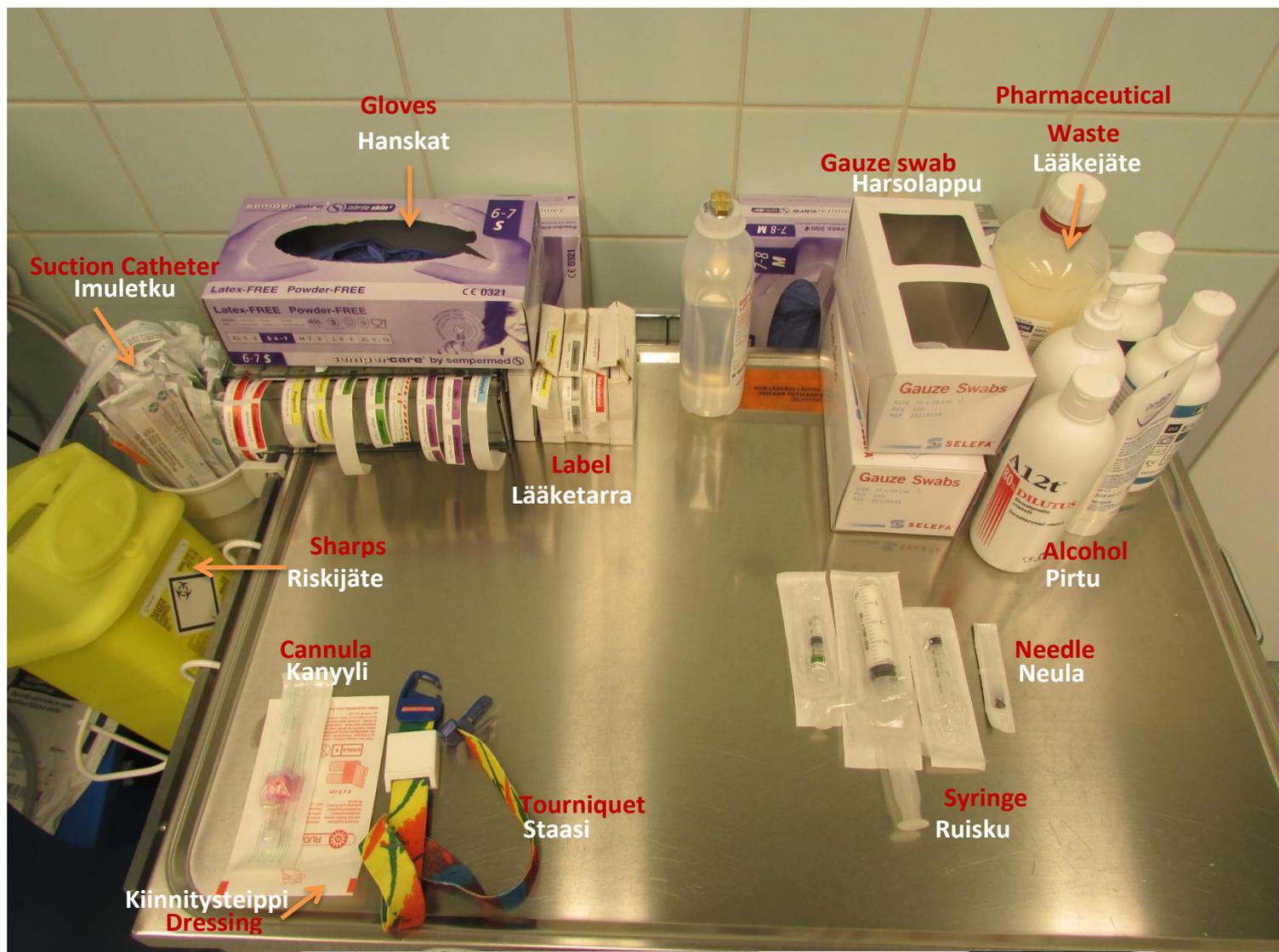
Medication Add Label

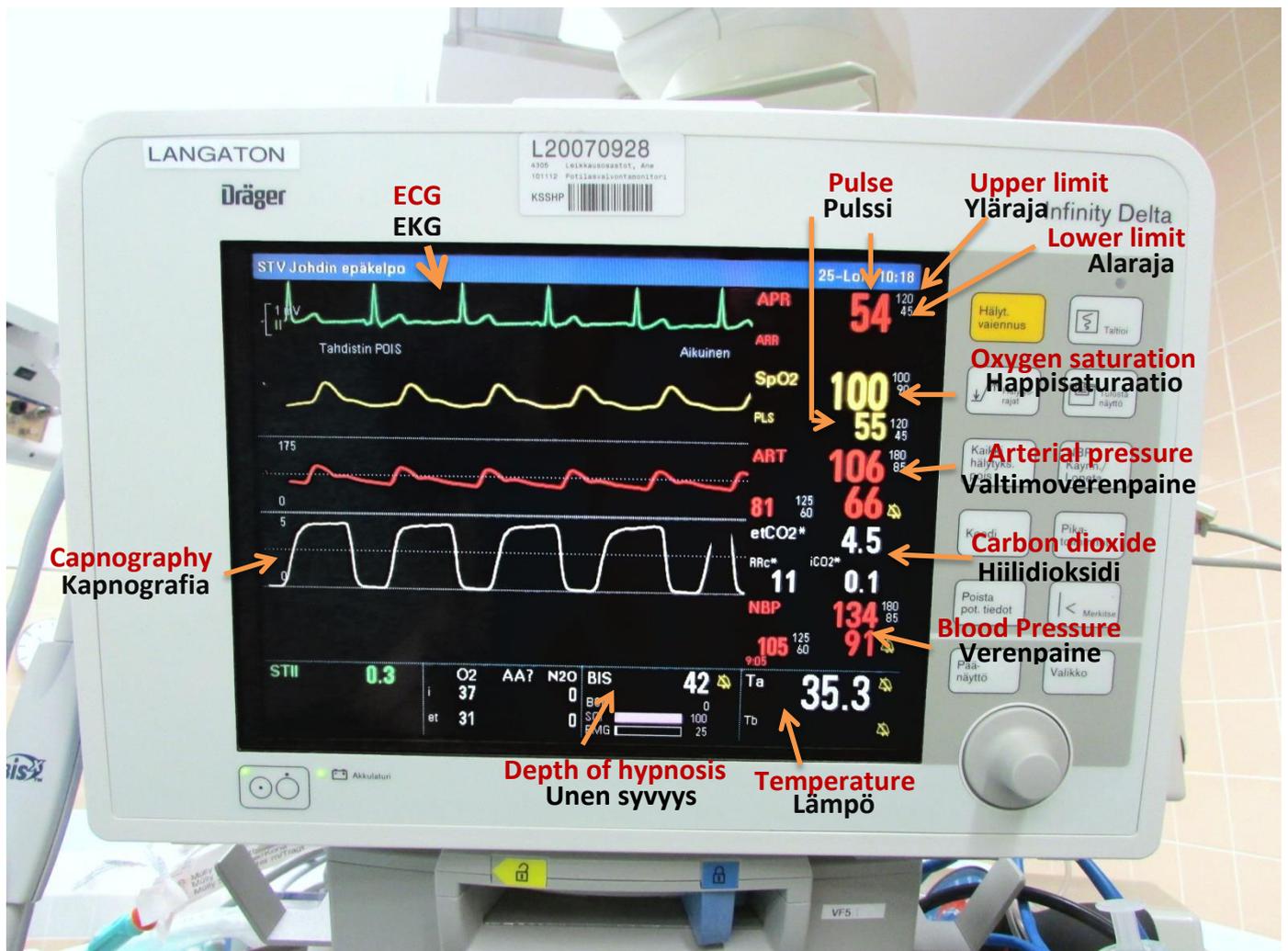
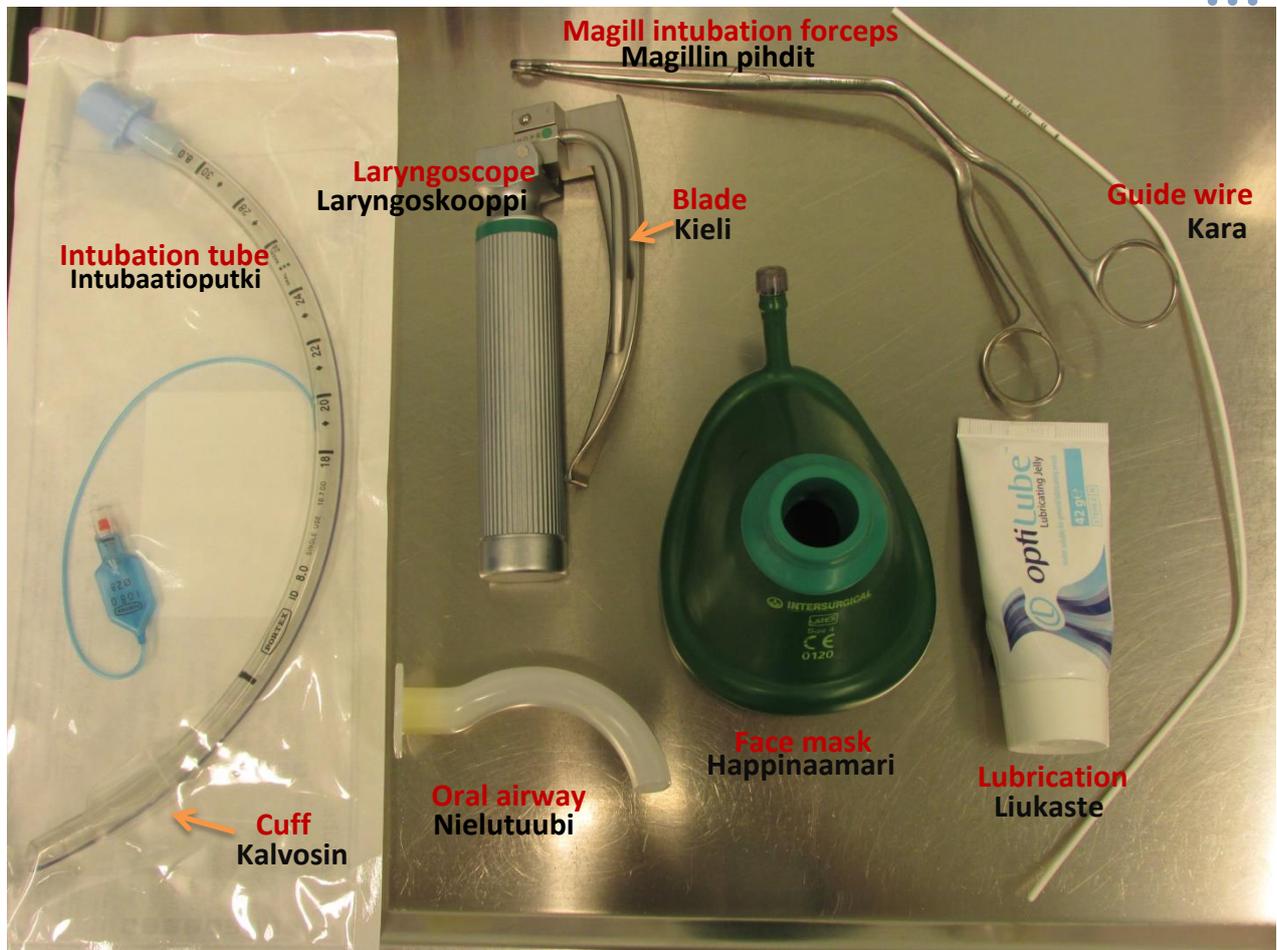
### 16.1.1 Surgical Checklist

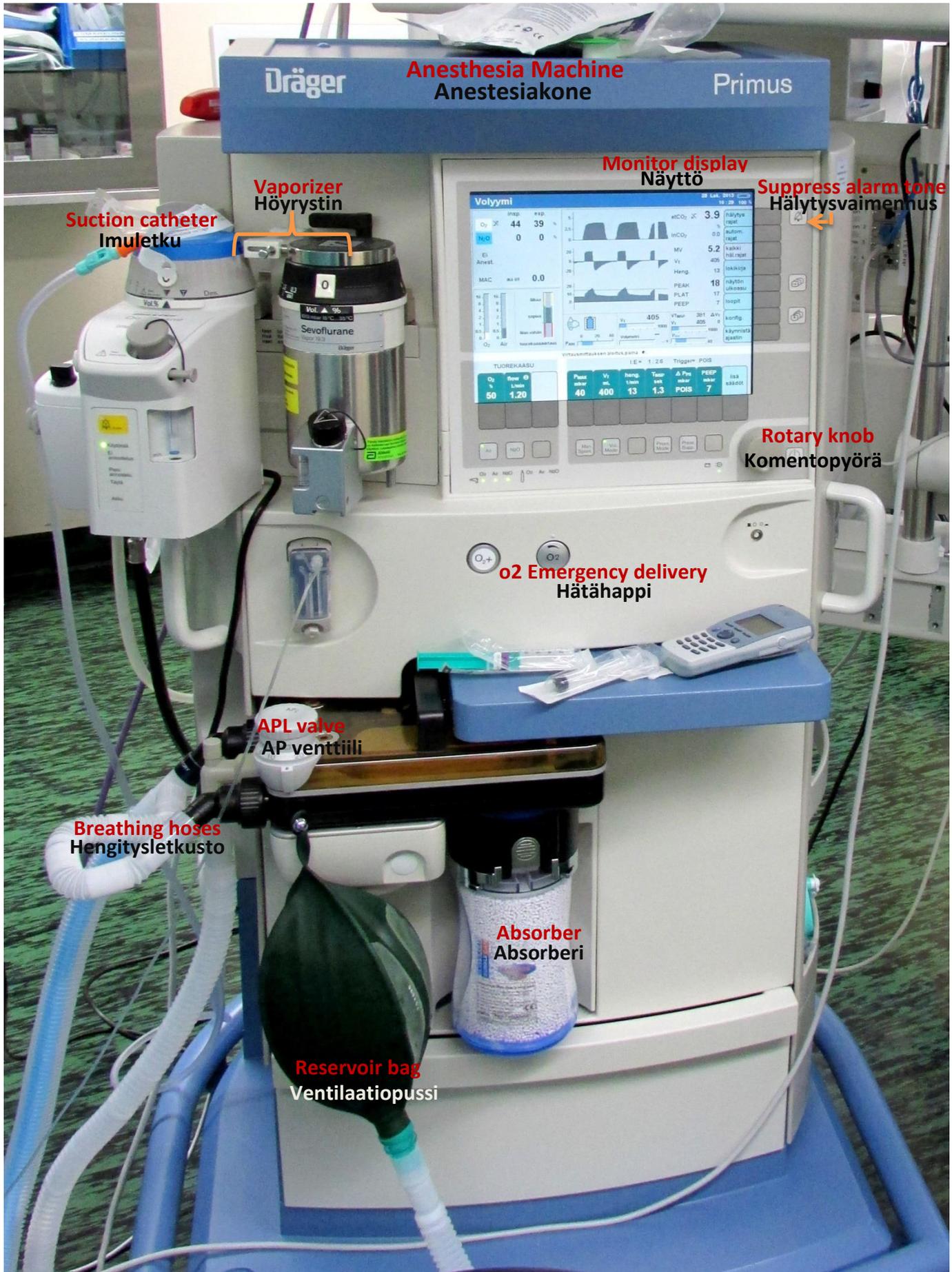
In the operating theater patient safety is promoted with the use of a surgical check list. The surgical checklist was established by the World Health Organization in cooperation with World Alliance for Patient Safety as an effort to reduce surgery related deaths and complications. The checklist used in the Central Finland Central Hospital is modified from the WHO's list to fit the hospital's purposes and customs. It is incorporated into the Leija electronic documentation system used in perioperative care. The checklist has timeouts at the patient admission to the operating room, before the incision, and prior the patient leaves the OR. The role of the nurse anesthetist in Central Finland

Central Hospital is to fill in the information described in the following paragraph. In the sign in the patient's identity and the surgical procedure are confirmed. The patient is enquired for known allergies to prevent harmful reactions to administered drugs or other used products. The possibility of a difficult airway is evaluated to avoid problematic intubation and prevent aspiration risk. The need for antibiotic prophylaxis is reviewed. The surgeon estimates the risk for blood loss exceeding 1000 ml and communicates it to the nursing staff. The nurse anesthetist prepares for replacing the fluid loss correspondingly. The nurse anesthetist ascertains whether there are any patient-specific concerns. She also informs the other team members does the patient have medications in use that increase the risk of hemorrhaging. This information is documented to the patient data. Near the end of the operation the nurse anesthetist enters care instructions given by the surgeon and possible need for antibiotics to the Leija system. The amount of blood loss is marked to the records. The use of surgical checklist ensures that important safety steps are taken to provide safe care. The checklist helps to minimize most commonly occurring but avoidable risks that endanger the health and well-being of surgical patient.

## 17 Picture Appendices







**Dräger Anesthesia Machine Anestesiakone Primus**

**Suction catheter Imuletku**

**Vaporizer Höyrystin**

**Monitor display Näyttö**

**Suppress alarm tone Hälytysvaimennus**

**Rotary knob Komentopyörä**

**O<sub>2</sub> Emergency delivery Hätä happi**

**APL valve AP venttiili**

**Breathing hoses Hengitysletkusto**

**Absorber Absorberi**

**Reservoir bag Ventilaatiopussi**

## 18 English-Finnish Wordlist

<b>Airway</b>	Hengitystie
<b>Alarm</b>	Hälytys
<b>Analgesic</b>	Verenpaine
<b>Anesthesia</b>	Anestesia
<b>Anesthesia machine</b>	Anestesiakone
<b>Anesthesiologist</b>	Anestesia lääkäri
<b>Anesthetic gas</b>	Anestesiakaasu
<b>Artery</b>	Valtimo
<b>Breathing hoses</b>	Hengitysletkusto
<b>Cannula</b>	Kanyyli
<b>Catheter</b>	Katetri
<b>Circulation</b>	Verenkierto
<b>Cork</b>	Korkki
<b>Cuff</b>	Kuffi, Kalvosin
<b>Depth of hypnosis</b>	Unen syvyys
<b>Diuresis</b>	Diureesi, virtsaneritys
<b>Documentation</b>	Kirjaaminen
<b>Drain</b>	Dreeni
<b>Drug, Medicine</b>	Lääke
<b>Epidural catheter</b>	Epiduraalikatetri
<b>Filter needle</b>	Suodatinneula
<b>Fluid balance</b>	Nestetasapaino
<b>Fluid warmer</b>	Nesteenlämmitin
<b>Gas exchange</b>	Kaasujenvaihto
<b>General anesthesia</b>	Yleisanestesia
<b>Guiding wire</b>	Kara
<b>Infusion</b>	Infuusio
<b>Infusion line</b>	Infuusioletkusto
<b>Infusion pump</b>	Infuusiopumppu
<b>Intubation tube</b>	Intubaatioputki
<b>Laryngeal mask</b>	Larynx maski, LMA
<b>Monitor</b>	Monitori
<b>Muscle relaxation</b>	Lihaselaksaatio
<b>Nurse Anesthetist</b>	Anestesiahoitaja
<b>Operating room</b>	Leikkaussali
<b>Oral airway</b>	Nielutuubi
<b>Oxygen Saturation</b>	Happisaturaatio
<b>PACU</b>	Heräämö
<b>Pain</b>	Kipu
<b>Position</b>	Asento
<b>Pulse</b>	Pulssi, Syke
<b>Respiratory frequency</b>	Hengitysfrekvenssi
<b>Suction</b>	Imu
<b>Surgical operation</b>	Leikkaus
<b>Temperature</b>	Lämpö
<b>Urine catheter</b>	Virtsakatetri
<b>Vein</b>	Laskimo

## 19 Finnish-English Wordlist

<b>Anestesia</b>	Anesthesia
<b>Anestesiahoitaja</b>	Nurse Anesthetist
<b>Anestesiakaasu</b>	Anesthesia gas
<b>Anestesiakone</b>	Anesthesia machine
<b>Anestesia lääkäri</b>	Anesthesiologist
<b>Asento</b>	Position
<b>Diureesi, virtsaneritys</b>	Diuresis
<b>Dreeni</b>	Drain
<b>Epiduraalikatetri</b>	Epidural catheter
<b>Hälytys</b>	Alarm
<b>Happisaturaatio</b>	Oxygen Saturation
<b>Hengitysfrekvenssi</b>	Respiratory frequency
<b>Hengitysetkusto</b>	Breathing hoses
<b>Hengitystie</b>	Airway
<b>Heräämö</b>	PACU
<b>Imu</b>	Suction
<b>Infuusio</b>	Infusion
<b>Infuusioletkusto</b>	Infusion line
<b>Infuusiopumppu</b>	Infusion pump
<b>Intubaatioputki</b>	Intubation tube
<b>Kaasujenvaihto</b>	Gas exchange
<b>Kanyyli</b>	Cannula
<b>Kara</b>	Guide wire
<b>Katetri</b>	Catheter
<b>Kipu</b>	Pain
<b>Kirjaaminen</b>	Documentation
<b>Korkki</b>	Cork
<b>Kuffi, Kalvosin</b>	Cuff
<b>Lääke</b>	Drug, medicine
<b>Lämpö</b>	Temperature
<b>Larynx maski, LMA</b>	Laryngeal mask
<b>Laskimo</b>	Vein
<b>Leikkaus</b>	Surgical operation
<b>Leikkaussali</b>	OR, operating room
<b>Liharelaksaatio</b>	Muscle relaxation
<b>Monitori</b>	Monitor
<b>Nesteenlämmitin</b>	Fluid warmer
<b>Nestetasapaino</b>	Fluid balance
<b>Nielutuubi</b>	Oral airway
<b>Pulssi, Syke</b>	Pulse
<b>Suodatinneula</b>	Filter needle
<b>Unen syvyys</b>	Depth of hypnosis/sleep
<b>Valtimo</b>	Artery
<b>Verenkierto</b>	Circulation
<b>Verenpaine</b>	Blood pressure
<b>Virtsakatetri</b>	Urine catheter
<b>Yleisanestesia</b>	General anesthesia

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