Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

Cardiovascular and respiratory monitoring in critical nursing care

A literature review

LAHDEN UNIVERSITY OF
APPLIED SCIENCES
Faculty of Social and Healthcare
Degree programme in Nursing
Registered Nurse
Bachelor Thesis
March 2016
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Koulutusohjelma Sairaanhoitaja AMK

NGUYEN, QUANG
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Potilaan sydämen ja hengityksen valvonta tehohoitotyössä
Kirjallisuuskatsaus

Akuutin hoitotyön oppinnäytetyö, 83 sivua, 5 liitesivua

Kevät 2016

TIIVISTELMÄ

Tehohoito on yksi haastavimmista ja vaativimmista hoitotyön erikoisaloista. Tehostetun hoidon osastoilla hoidetaan potilaita, joilla on henkeä uhkaava sairaus tai muu vastaava tilanne. Tehohoidon ensisijainen tavoite on pelastaa ihmishenkiä, vähentää sairauden astetta ja optimoida toipumisennustetta. Kriittisesti sairaiden potilaiden hoidossa korostuu vahva tietotaito, jota kokemukset vahvistavat.

Sydän- ja hengityselinten sairaudet ovat yleisiä syitä tehohoitoon päätymisessä. Potilaan sydämen ja hengityksen toimintaa seurataan jatkuvasti. Näitä peruselintoimintoja seurataan kliinisesti ja erilaisten laitteiden avulla, joka edellyttää vahvaa hoitotyön osaamista.

Tämä opinnäytetyö tehtiin Lahden ammattikorkeakoulussa ja menetelmänä käytettiin systemaattista kirjallisuuskatsausta. Tietoja kerättiin luotettavista akateemisista englannin- ja suomenkielisistä tietokannoista. Erilaisia kuvia, piirroksia, animaatioita sekä tilastoja hyödynnettiin myös.

Opinnäytetyön tarkoituksena oli kuvata potilaan sydämen ja hengityksen seurantaa tehohoitotyössä. Tämän opinnäytetyön avulla sairaanhoitajaopiskelijat voivat lisätä teoreettista tietoa potilaan sydämen ja hengityksen toiminnasta ja seurannasta.

Asiasanat: tehohoito, hengityksen valvonta, sydänvalvonta, suomalainen tehohoito, tehohoidon sairaanhoitajat.

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Cardiovascular and respiratory monitoring in critical nursing care. A literature review

Acute care Bachelor Nursing

83 pages, 5 pages of appendices

Spring 2016

ABSTRACT

Critical care is a modern challenging hospital specialty that provides specialized treatments for patients with life-threatening illness. The primary goal of critical care is saving lives, reducing degree of illness and optimizing recovering prognosis. Thus, nursing requirements in critical care are high, including professional skills, expertized knowledge base and profound experiences in dealing with critical condition patients.

Cardiovascular failures and respiratory failures are common reasons of admissions to critical care units. The monitoring of cardiovascular and respiratory functions are, therefore, typical procedures in critical care routine. Those monitoring processes are complicated, requiring various understanding of monitoring principles, systems, devices, techniques as well as necessary nursing interventions.

This thesis is performed as part of nursing program study at Lahti University of Applied Sciences and endorses systematic literature review method. Data gathering is done through reliable academic database resources both in English and Finnish, assuring the reliability of the final work. Various pictures, illustrations, animations, statistics are also utilized in this thesis.

The aim of this thesis is to describe the principle processes of cardiovascular and respiratory monitoring as part of critical care routine. This thesis emphasizes the importance of nursing knowledge in critical care, thus can be used as study material for nursing students at their final stage of studies to increase theoretical and practical knowledge.

Keywords: Critical care, respiratory monitoring, cardiovascular monitoring, Finnish critical care, critical care nurses.

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GLOSSARY

ICU	Critical care unit
PAC	Pulmonary artery catheter
ECG	Electrocardiographic
CCU	Coronary care unit
MAP	Mean arterial pressure
CVP	Central venous pressure
RVEDP	Right ventricular end-diastolic pressure
LVEDP	Left ventricular end-diastolic pressure
PAWP	Pulmonary artery wedge pressure
EI	Endotracheal intubation
ABG	Arterial blood gas
$ETCO_2$	End-tidal carbon dioxide
COPD	Chronic obstructive pulmonary disease
OPA	Oropharyngeal airway
NIV	Non-invasive ventilation
VALI	Ventilator-associated lung injury
VILI	Ventilator-induced lung injury
SIMV	Synchronized intermittent mandatory ventilation
A/C	Assist/Control
PSV	Pressure support ventilation

PCV	Pressure-controlled ventilation
APRV	Airway pressure release ventilation
VGPO	Volume-guaranteed pressure options
CPAP	Continuous positive airway pressure
BiPAP	Noninvasive bilateral positive-pressure ventilation

1 INTRODUCTION

Inability to address acute downturn of critical hospitalized patients might lead to cardiopulmonary arrest, even mortality. Mostly, at general hospital wards, patient monitoring happens at a low level and based generally on nurses' observations. Typically, the patient's phisological data will be recorded once or twice in every working shift. Based on those collected valuables, doctors are to decide appropriate medical interventions in order to prevent the patient's health deterioration (Goldhill et al. 1999, 529 – 534). On the other hand, in immense care facility such as Intensive Care Unit (ICU), patients are literally under continuous and comprehensive monitoring and every single change in the patient's physiological variables are taken into account. The most crucial values monitored are heart rate and respiratory rate (McGain et al. 2008, 380 - 383).

Many nursing students studing at Finnish polytechnic programs seem to lack practical knowledge of nursing monitoring in ICU departments as well sufficient experiences regarding how to act in such critical situations (Lakanmaa et al. 2015). As the result, they encounter considerable clinical challenges during practical trainings, leading to stressful emotion at the workplace.

The idea of this thesis topic takes roots from the authors' own interests and needs for self-studies about critical care. As an important part of the research, the authors will analyse the most common characteristics of critical cardiovascular and respiratory monitoring in the course of intensive care units. The purpose of this systematic research is therefore emphasizing the importance of critical care in nursing care as a whole, giving an educational overview playing as a supporting role for nursing students in clinical training as well as their starting point of the career. This thesis can be used as a study material for the nursing students at their final stage of studies and through this thesis they can learn more about Finnish critical care system and the role of nurses in the ICUs.

2 THEORETICAL BACKGROUND

2.1 Critical nursing care

With just over more than 50 years of development, critical care is a fairly modern hospital specialty that has been rigorously developed to meet new challenges in our healthcare system (Wildsmith 2003, 1200 - 1203). Literally intensive care units (ICU) are variable and designated to specifically focuse on particular kinds of treaments. Not all hospital will arrange their ICU facilities alike in terms of structures and competent equipments. In fact, ICUs vary from hospital to hospital based on the characteristics of national healthcare infrastructure, provided services, sizes, technologies, available staffs and specific expertise of the organization (Williams & Wilkins 2003). An ICU will be located with appropriate departments and facilities to make sure the multidisciplinary needs of critical care are ensured. It is inevitable that the economic and potilical factors play an important role in the variations that are unique in each and every hospital's administration. Therefore, the ICUs' characteristics can be defined, for example, by the regional population or the number of hospitals closeby as well as the needed healthcare services in that particular area. ICU patients, moreover, can also be defined by their diagnosi, types of illness, prognosis or even the patient's age (Williams & Wilkins 2003). Examples of ICUs can be named as follows: Cardio-thoracic surgical ICUs, neurosurgical ICUs, pediatrics ICUs, trauma ICUs, coronary ICUs etc (ICCMU 2009).

Even though ICUs characteristics differ from hospital to hospital, country to country, the main core and purpose of ICUs stay that same: to provide special expertised treatments, needed facilities and specially trained healthcare personnel for patients with life-threatening illnesses (AIHW 2012). Critical care purpose is saving lifes, reducing degree of illness or disability, minimizing treatment time as well as optimizing recovering prognosis (Blomster et al. 2001). The patients treated in ICUs are highly at risk of failures or dysfunction of one or more organs that require continuous comprehensive mechanical and pharmacological monitoring and supporting (Singer & Webb 2009). Those patients are usually are treated with cardiovascular diseases, decreased consciousness of different reasons, respiratory problems, renal, serious circulatory disorders, metabolic, brain injuries, serious after-surgical care, complicated multiple trauma, burns or servere sepsis (HUS 2016).

As critical care services are expensive and costs lots of budget from healthcare system (Leino-Kilpi & Välimäki 2004), addmission to ICUs can be influenced and categorized by different factors, mainly based on the patient's critical degree to utilize the best benefits service provided by ICUs. Admission to ICUs should be made immediately if considered needed and appropriate (Lund 2011).

Critical illness is defined and categorized based on the patient dependency levels. Universal tools to measure the patient dependency have not been unitedly agreed and vary from place to place (Galley & O'Riordan 2003). According to Department of Health for England (DHE 2003), the patient dependency levels can be recognized as such:

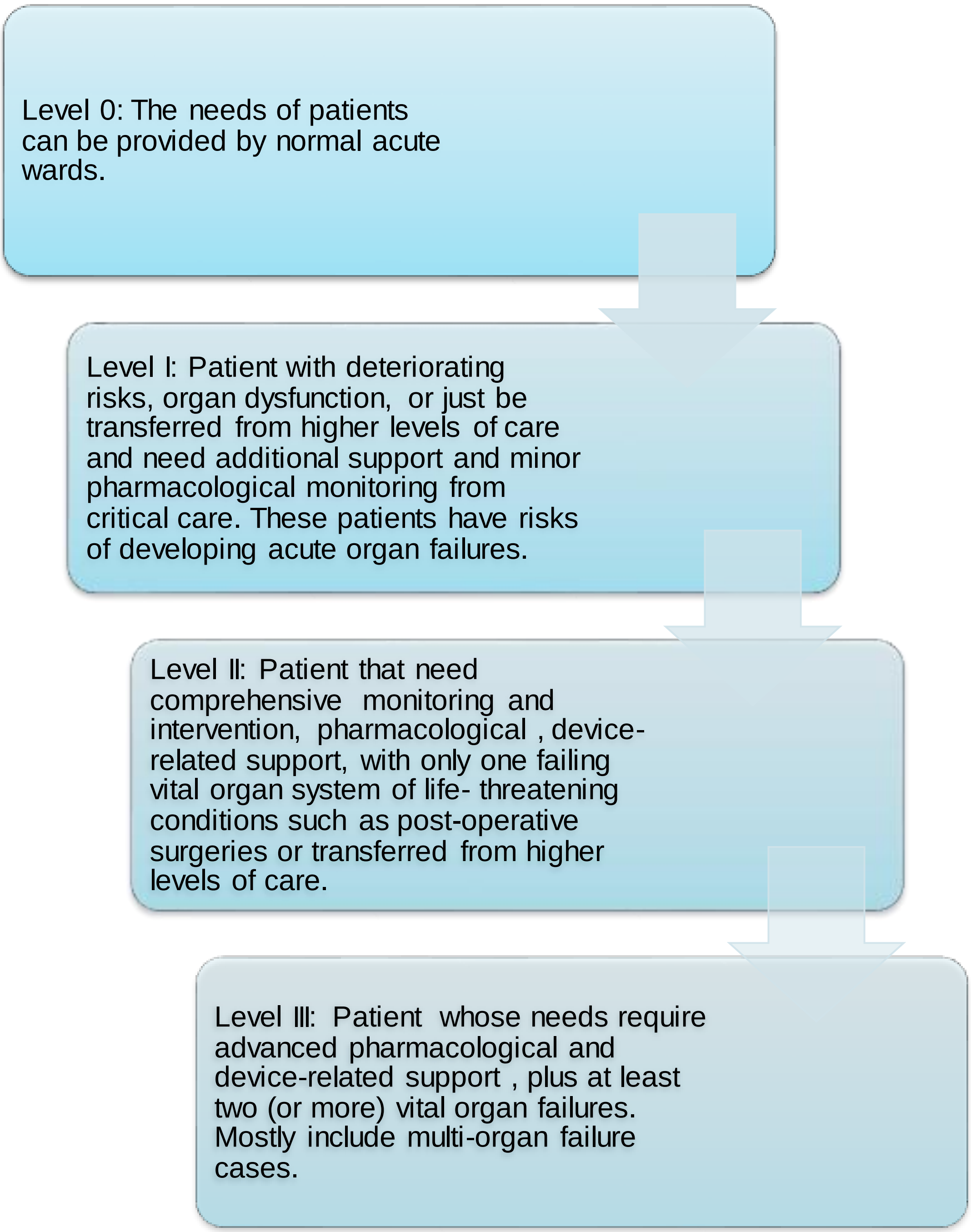


Figure 1. The patient dependecy levels (DHE 2003)

In ICUs it is inevitable that medical, anesthesiological, surgical, and radiological professionals must be available on a 24/7 basis (Minvielle et al. 2008). Participating in the critical care are healthcare professional teams include director of the ICU, medical staff members, doctors, medical trainees, nursing staff (head nurse, nurses, nurses in training), healthcare personnel (technicians, physiotherapists, radiology technician, pharmacists, psychologists..) as well as cleaning personnel (Ramnarayan et al. 2010). The charactertistics of work and duty in ICUs are complex and dynamic including different overlapping responsibilities, which require essential and proficient cooperation of various professionals.

2.2 Cardiovascular monitoring in ICU

Cardiovascular monitoring is one of the typical procedures in intensive care units (Stover et al. 2009). Basically, invasive techniques are used as monitoring tools. They are pulmonary artery catheter (PAC) and peripheral artery catheters (Leibowitz & Oropello 2007, 162-176). In addition to that, PiCCO system is also used in certain cases (Antonini et al. 2001, 447 - 456).

As a matter of fact, heart rhythm disorders and their coming along cardiovascular symptoms are probably challenging to detect. Reason is that they often come and go in an intermittent pattern. Doctors or physicians examine cardiovascular activities based on tests as eletrocardigram. Such tests, however, only provide information at a point of time, not in a long run. After that, until when patients are diagnosed with arrhythmia, patients are still at risk of further symptoms or cardiovascular consequences (Crossley et al. 2011, 1181 - 1189).

In order to detect the cause of recurrent fainting or unclear stroke, atrial fibrilaation, the patient's cardiovascular activity has to be monitored effectively over time. Doctors can only address the problem precisely base on the overall picture as a whole (Krahn et al. 2003).

In spite of the variation in different types of cardiac monitors, all monitoring systems have there three basic components: a display system, a monitoring cable, and electrodes. Electrodes are placed on the patient's chest to receive the electrical current from the cardiac muscle tissues. The electrical signal is then carried by the monitoring cable to a screen, where it is magnified and displayed. The display can be obtained both at the patient's bedside and at a central station, along with displays from other patients' monitors (Shaw & Chishti 2016).

2.3 Respiratory monitoring in ICU

Respiratory failure is the most common reason cause of ICUs admissions. There are various diseases or accidents that can lead to impair of respiratory system which makes it unable to maintain the gas exchange function for metabolism (Camporota & Rubulotta 2012). Respiratoring monitoring, therefore, plays a critical role in saving the patient from acute respiratory diseases. In contrast to other types of monitoring, respiratory monitoring often faces barriers in deciding the prioritized or signalized variables due to intermitten respiratory patterns. Monitoring respiratory activities can be done either manually or by monitoring devices (Brochard 2012).

Respiratory monitoring in ICU means the continuos process of recording the patient's respiratory activities. Respiratory is one of the basic vital signs of human being. Generally, respiratory monitoring includes: Gas exchange, respiratory mechanic, lung volumes, cardiopulmonary interactions and lung inflammation (Guyton & Hall 2006, 471 - 522)

According to the American Society of Anesthesiologists (2009, 1004 - 1017), all guidelines for respiratory activities monitoring have similarities:

a. Continuosly monitoring of oxygenation by pulse oximetry (Becker et al. 2009)
b. Ventilation should be ensured continuously.

Inspite of modern development of technology in medical health equipments, simple respiratory mesurements are often underused. Reasons are mostly because of lack of understanding the physiology of specific monitoring system. Hence, continuosly increasing training and offering opportunity for approaching newly produced monitoring devices are unavoidable for healthcare worker nowadays. (Brochard 2012).

3 AIM OF THESIS AND RESEARCH QUESTIONS

The aim of this thesis is to describe the principle processes of cardiovascular and respiratory monitoring in critical nursing care. The goal is to provide comprehensive material about critical nursing care.

During the course of the research, the authors attempt to provide a comprehensive picture of critical care nursing. Due to the scope of the thesis, only cardiovascular monitoring and respiratory monitoring will be emphasized. Through the analysis of those factors, nursing students will be facilitated with the most commonly critical cardiovascular and respiratory illnesses that require intensive care. In addition, by reviewing the research, students should also be introduced to different devices/equipments used in cardiovascular monitoring and respiratory monitoring.

The research questions in this thesis are:

1. What is critical nursing care?
2. How to monitor cardiovascular activities in ICUs?
3. How to monitor respiratory activities in ICUs?

4 THESIS IMPLEMENTATION

4.1 Systematic literature review methodology

A systematic literature review creates a strong foundation for the research methodology. The purpose of a literature review is to show how the subject has been previously studied and from which perspective it is related to other studies. The literature review focuses on the topic's essential literatures, including magazine articles as well as the analysis of other key publications. The descriptive review of literature is the most common method used in the literature review. It is also the least dense material that does not limit the choice of methodological criteria. After the descriptive literature review has been done and data is voluminously collected, the research questions will come up to challenge the researchers' unanswered findings (Boote 2005, 3 - 15). As a consequence, the systematic literature reviews, research objectives as well as research questions must be carefully considered (Beile 2006, 32 - 35).

This thesis will be conducted by systematic literature review method. A systematic review of the literature is a summary of a particular topic, which has been researched before with high-quality content. The outcome of the literature review will address directly to research questions. The researchers also use systematic literature review in researching through various research materials. Understaning the literature review method and its applications is beneficial to all healthcare professionals. Systematic reports are evidence-based foundation for nursing interventions. In addition, treatment guidelines should be based on systematic reviews. (Whitemore & Knaft 2005)

The authors have applied literature review method in providing the answers for thesis questions:

1. What is critical nursing care?
2. How to monitor cardiovascular activities in ICU?

3. How to monitor respiratory activities in ICU?

The purpose of the thesis is not to cover all the related information, but focuces on providing supporting information for nursing students to improve their competences during practical training.

In order to facilitate the literature review method in this thesis, reliable databases are utilized, including ARTO, CINAHL, COCHRANE, EMERALDINSIGHT, MEDIC, and PUBMED database. The result articles were retrieved using key words: critical nurs*, teho sairaanhoit*, cardiovascular monit*, respiratory monit*, acute cardiovascular diseas*, acute respiratory diseas*, cardiovascular monitoring devices, respiratory monitoring devices. In addition, combining word “AND” is also used. All the variables range from year 2005 – 2016, assuring the updateness of the articles. Search language is in both English and Finnish. In order to secure the research’s reliability, the thesis authors approved only doctoral researches, original studies, review articles, dissertations reports and master's theses.

The data was analyzed and paraphrased according to deductive content analysis method. In the content analyzing process, the authors put excessive effort in describing concisely the contents of documents. When describing quantitative contents of the retrieved documents, contents of the breakdown is mentioned. Deductive content analysis provides the method to define the categories definition based on historical data. Moreover, this type of analysis offers a tool for searching process of the contents, which are images of the expressions (Tuomi & Sarajärvi 2009, 113-117)

4.2 Literature review planning, selecting, and quality assessment

In the early stage of implementing literature review, planning is the most important step. Literature review planning guides the thesis to the right direction and provides a logical structure to the research. At this stage, previous researched literatures are reviewed. Based on that, the authors will have an overall understanding about the related area of the thesis and define the necessarality of their thesis topic. The thesis question will drive the data gathering at this stage and subsequently the systematic literature review methodology will be taken into used to handle the gathered data.

Familiarizing to available researches is the first step of planning. Data gathering is done through both academic Finnish sources and academic English sources. Searching phrases used include: “critical care”, “intensive care”, “Pulmonary gas exchange”, “ECG”, “cardiac monitoring”, “respiratory monitoring”, “cardiovascular disorder”, “ischemic”, and “arrhythmia”. Based on the results collected from searching process, the authors have general understanding about the previous researches on the topic. In addition to that, knowing what previous studies are available also help the thesis process focus on the thesis relevancy. Not only the above-mentioned academic database, but also Theseus-publication resources have been used in order to seek for available researches on the topic. After the planning process, the authors realized that although various researches about critical nursing care have been studied before, a comprehensive guide to monitor cardiovascular and respiratory, however, remains undone. Hence, the answers for thesis question are relevant and necessary. The publications which have been reviewed are from different University of Applied Sciences throughout Finland.

The below table illustrates in detailed the database resources that have been used in the planning process.

Table 1. Database used in reviewing literatures.

Database	Description
ARTO	Finnish article reference database
CINAHL	International healthcare research database (articles, publication, etc.)
COCHRANE	International (also Finnish) medical database

EMERALDINSIGHT	Global publisher linking research and practice
MEDIC	Finnish medical sciences database. Include: medical, oral medical and healthcare scientific publication
PUBMED	International medical literatures

In additions to those above- mentioned databases, many other literature reviews and publications related to cardiovascular monitoring and respiratory monitoring are taken into information gathering process. The critical purpose, above all, is to get as wide range of literatures as possible. In order to ensure of the thesis' relevancy, there are certain criteria primarily set to filter the most important material from the vast results. Those criteria will be discussed in table 2 which includes the criteria for results approval or exclusion.

As the matter of fact, this thesis' literatures have been reviewed from international databases, Finnish databases as well as Vietnameses database. Information gathering has been scanned through Finnish recommendation sources for doctors and nurses such as: Terveysportti, Duodecim, Finnarest, Hotus and Käypähoito. Medical science books which are used vary from Finnish, English to Vietnamese languages.

Table 2. Criteria for result approving and excluding

Criteria for result approving	Criteria for excluding the result
Results range from year 2005 – 2015	Results range in years before 2005
Literature language in Finnish, English or Vietnamese	Other than Finnish, English or Vietnamese

Master, PhD thesis, science researches, medical publication.	Colleage researches, polytechnic thesis, small reports.
Publication with high reliability	Viewpoints, television interview, newspaper.
Whole articles, publications	Only part of the publications (Abstract, summary, etc.)
Intent to adult health	Literatures about children.
Contents answer the research questions	Contents do not answer the research questions
English, Finnish university textbooks from prestigious international publishers	Other than English, Finnish textbooks from prestigious international publishers.
Articles intent for doctors and nurses	Articles intent for physiotherapeutists, not healthcare professionals.

4.3 Qualitative content analysis

The contents of this thesis were analysed using qualitative content analysis methodology. Content analysis is understood as a systematic, logical analysis technique for simplifying the vast complicated contents into certain categories based on certain coding rules (Potestio et al. 2015, 1 - 11). According to Hsieh Hsiu-Fang and Shannon Sarah E. (2005), although being used frequently, content analysis should be considered as a multiaproaches tool in order to interpret meaning from the data content rather than as a sole method. As a matter of fact, content analysis has been used actively in nursing researches in recent years (Hsieh & Shannon 2005, 1277 – 1278).

By interpretation, certain content could be interpreted in various ways and the understanding hence seemingly depends heavily upon subjective perspective. In addition to that, qualitative researches such as interviews and observations require massive cooperation efforts among researchers to have a trustworthy approaching (Santiago-Delefosse et al. 2016, 142 – 151).

After reviewing different approaches in qualitative content analysis, the authors have considered the most accepted and trustworthy approaches. Finally, the contents of this literature review applied "Qualitative content analysis in nursing research" formation which was developed by Graneheim and Lundman in 2004 (105 – 112).

In a nutshell, the contents which were retrieved from common literatures were at original "raw text". After that, those contents were condensed in a more compact form but still maintain their core original meaning. Consequently, condensed meanings of the input were put into sub-theme and main theme. The main themes, which are the final purpose of this analysis process, are the answers to the thesis questions. In other words, the main themes are the concept describing critical care, cardiovascular monitoring and respiratory monitoring in critical nursing care.

Table 3 illustrates some of those principles in detail.

Table 3. Example of results analyzing process

Original inputs	Condensed meaning of the inputs – Interpretation	Sub-theme	Theme
"….Diferent models would create hemodynamics in acute heart	Hemodynamic monitoring produces indicators for heart diseases	Hemodynamic monitoring supports diagnosis	HEMODYNAMIC MONITORING

diseases patients...”			
“…Hemodynamic monitoring carries out the main aim as correction to the cardiovasculare system assessment and its evaluation of oxygen demand…”	Hemodynamic monitoring guide therapies to optimize cardiac function		
“… Gradual risk from unstable arrhythmic could be the underline of hemodynamic death…”	Hemodynamical arrhythmias increases mortality	Hemodynamical arrhythmias is life-threatening	
“…Cardiovascular unstabe rhythm happens quite usual in many patients with disturbance heart diseases…”	Hemodynamic effects during arrhythmias might be lead by pathology		
“…Lacking of understanding about serious preeclapsia in	Spinal anesthesia might cause severe	Residual hemodynamic abnormalitites causes	

patients with spinal anesthesia can caus hemodynamic responses…"	hemodynamic events	postoperative complications	
"…Severe hypothermia as the consequence in cardiac arrest on patent with hemodynamics myocardium…"	Hemodynamic arrthymia causes hypothermia after surgery		
"…SvO_2 deterioration might be seen as an early warning of cardiopulmonary inadequacy prior to hemodynamic disturbance occurs…"	Hemodynamic monitoring is indicated as a mechanism to assess balace of oxygen supply	Hemodynamic monitoring measure oxygen delivery	
"…alterations in vascular resistance (afterload), or alterations in myocardial contractility…"	Hemodynamic monitoring indicate oxygen insufficiency		

5 RESEARCH FINDINGS

5.1 Critical nursing care

5.1.1 Critical care in Finland

In Finland, critical care units have been established for over 50 years with updated changing developments to meet new challenges. Finnish critical care origin took its first roots from surgerical care requirement. The first ICU was established in 1964 in Kuopio (Siirilä 2008, 2). Currently there are 46 critical care units being in charge of giving care for over 28.000 patients every year (STHY 2015). Lists of those ICUs can be found from the Appendix 1 Page 82.

In Finland, critical care units are categorized into three different categories. The first category includes Finnish university hospital ICUs, which provide various critical cares for different patient groups. The second category includes Central hospital ICUs, which provides all various critical cares, but do not provide care for special groups such as heart- and neurosurgical patients. The third category is hospital's designated high surveillance deparment (in Finnish named "tehovalvontaosasto"), which offers immediate critical care for the patient but after that the patient will be transferred to other critical care units for follow-up (Pyykkö 2014).

Critical care units are crucial part of Finnish specialized medical care section, which can be illustrated in the following graphic:

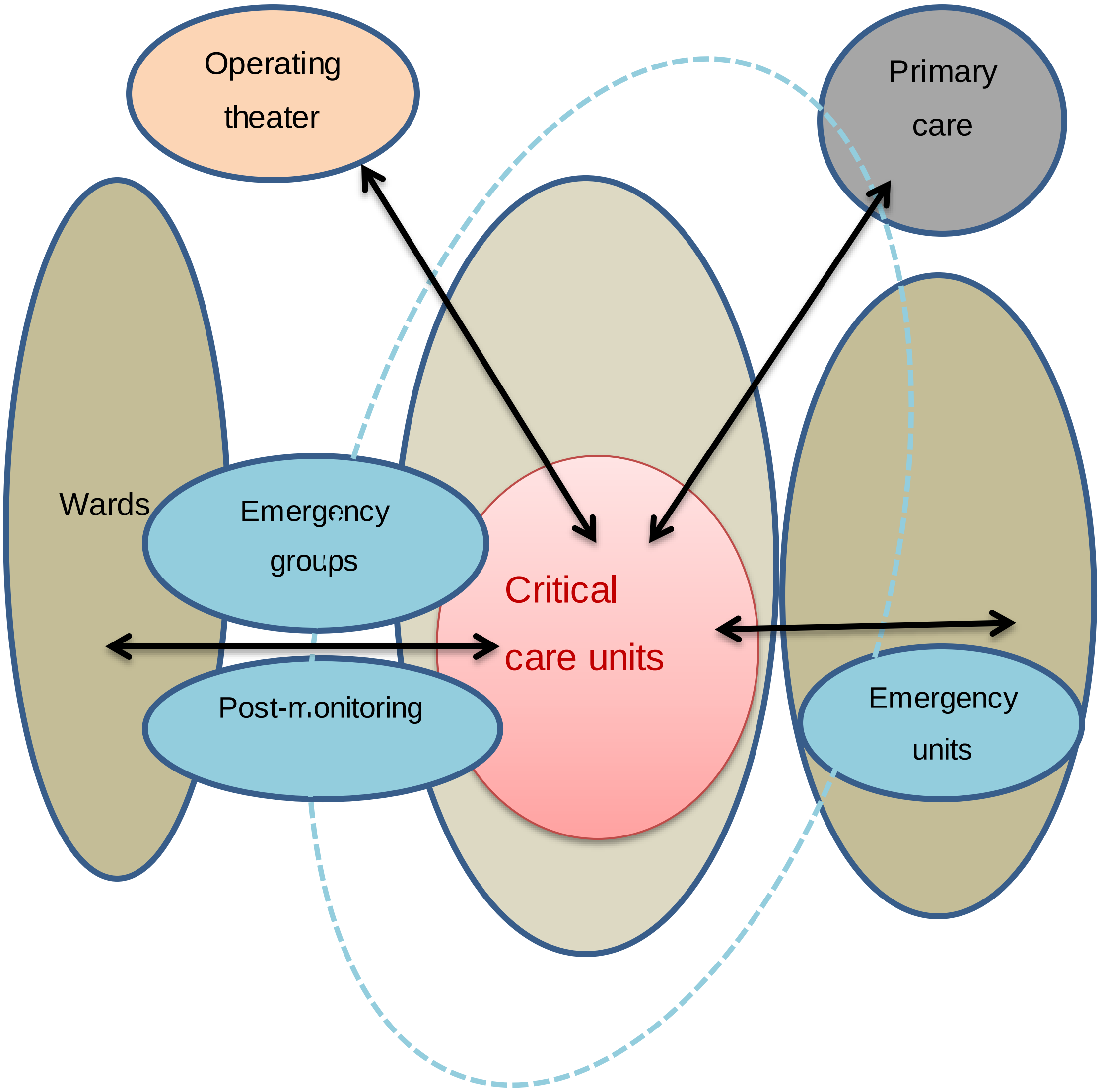


Figure 2. Critical care as part of specialized medical care in Finnish healthcare system (MSAH 2013)

One third of the ICUs patients in Finland are over 70 years old and treating time of one case is calculated as around 3.4 days, but it can vary from a few hours to few weeks individually (Meriläinen 2012). The needs for critical care in Finland are estimated to increase as the population ages fast in the near future (Rosenberg et al. 2014, 14 – 16). Therefore, it is estimated that demand for ICU beds in Finland will increase 19% by 2020 and 25% by 2030 (Reinikainen et al. 2007, 522 – 529)

From the period between the years 2001-2008, the rate of hospital mortality in Finnish ICUs was 18.4%, which was relatively good compared to other countries. Increasing age is a huge factor contributing to hospital mortality, with up to 30% patients are over 80 years old. ICU males patients make up a majority number compared to females. Respiratory failure cases in ICUs increase especially in winter seasons, contributing to more mortality during this time of the year (Reinikainen 2012).

Below are the collected facts/ figures concering Finnish critical care:

Table 4. Finnish intensive care figures (Varpula 2011)

Sessions	About 17.000/ years
Average treating time	About 3 days
Costs of one day	About 1800 Euro
Cost of whole session	About 5500 Euro
Total cost	Over 90 millions Euro
Percentage of critical care cost out of total country's health expenditures	About 0.5%

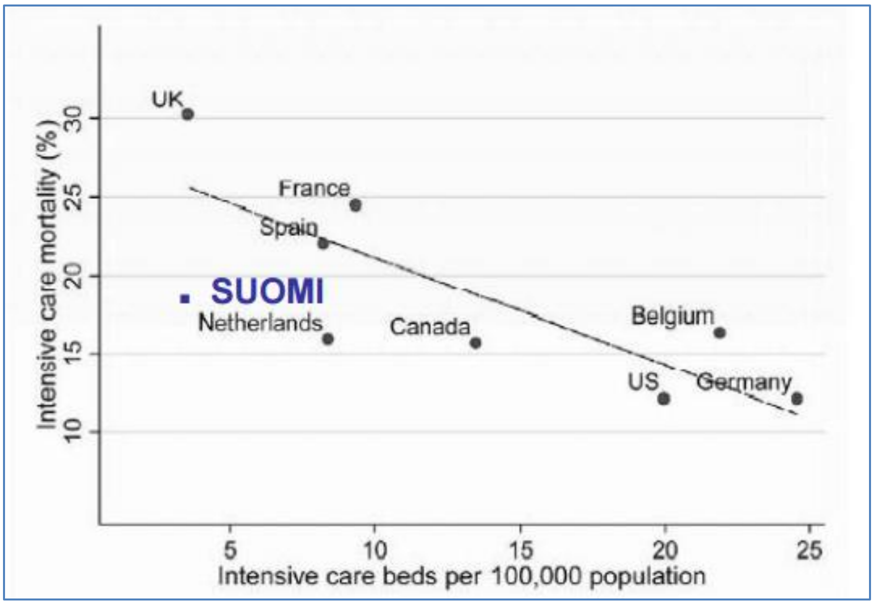


Figure 3. Intensive care mortality and intensive care beds per 100.000 population in different countries (Varpula 2011)

As can be seen from the figure 3 above, Finland's mortality during ICU care is less than 20%, higher than Netherlands, Canada, US, Belgium, Germany and much lower than UK, France and Spain. Intensive care bed per 100.000 poppulation in Finland is fewer than 5 beds, much fewer than other listed countries.

As generally understood, the longer the patient has to wait for ICU admission, the higher the risk of mortality is. Details of this correlation can be illustrated in figure 4 below:

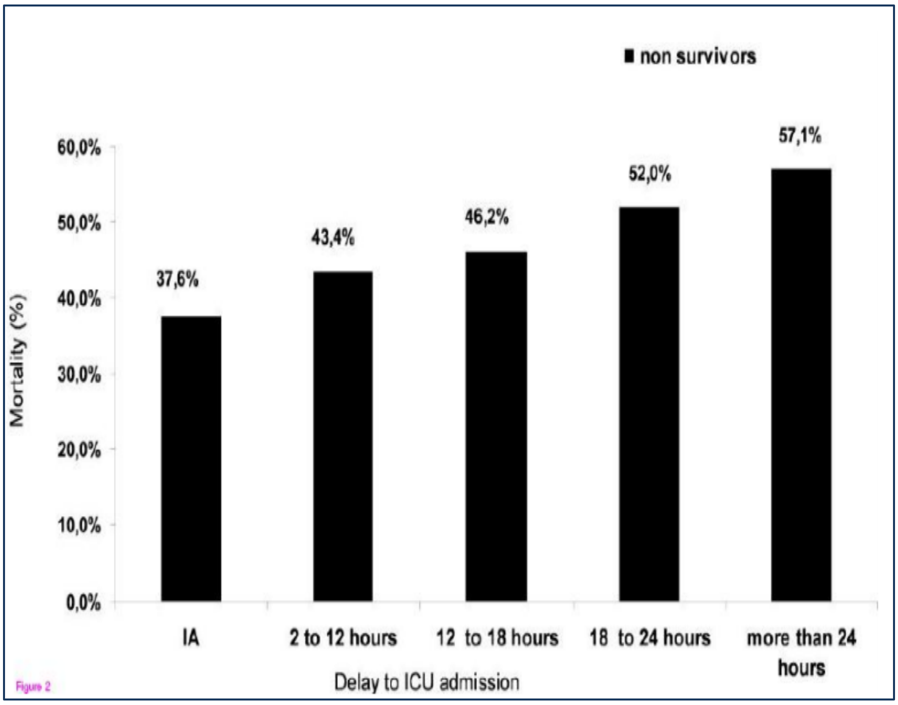


Figure 4. Delay time to ICU admissions versus mortality (Varpula 2011)

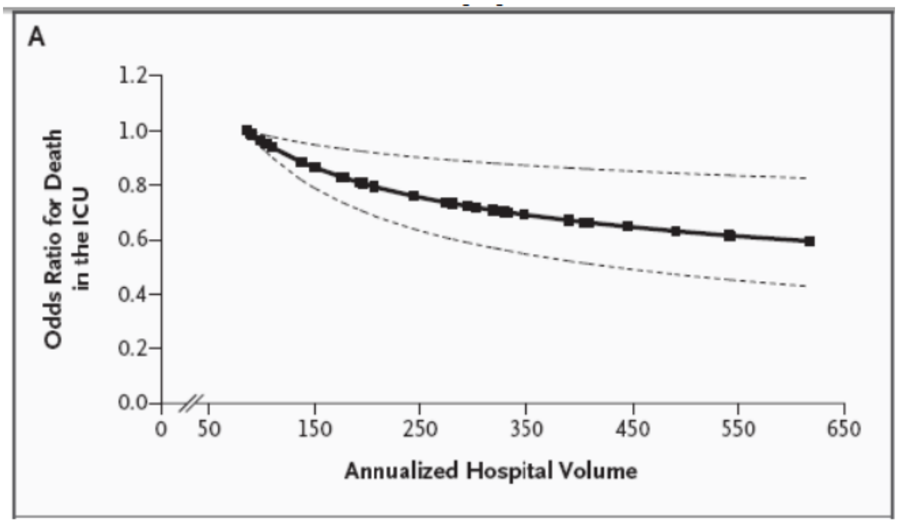


Figure 5. Odds ratio for ICU deaths in association with annualized ICU hospital volume (Varpula 2011)

Clearly can be seen from figure 5 that, the death rate in ICUs decreases dramatically in contrast with increasing admissions, which relatively decates efficiency and good quality of ICUs care in Finland.

In Finland, the quality of critical care has ben assessed from 1994 through quality assosiations based on treatment outcomes and comparisonal values. Nowadays all the Finnish ICUs are included in those quality surveillance (Aarno & Petteri 2012, 318 – 320). Usually, mortality percentage is used to determine outcome of critical care, as data is available in the registered system. In terms of surgical operations, mortality is counted as death during 30 days after surgeries. But those mortality percentages in general do not provide a correct image of quality as the mortality figure depends on different factors. Those factors include hospital's clinical practices and particular criteria to transfer patients to other follow-up departments, in which case the patient can survive in the hospital but then passes away after such transfers. Age can also an important player in mortality.

5.1.2 Nursing role in critical care

Nurses in critical care units are registered nurses (graduated from bachelor degree program) with additional specialized trainings to qualify with demanding requirements of critical nursing care. Working in ICUs requires special skills and strong working endurance (Rosenberg et al. 2014, 16).

The role of an ICU nurse might be slightly different in different hospitals and different countries. In the ICUs, nurses make up the largest portion of professional personnel and there are approximately over 500.000 ICUs nurses currently working all over the world. Nurses' jobs directly affect the outcomes of the treatment, helping reduce complications risks and mortality rates as well as promoting the patient's safety. (Coombs et al. 2007, 83 – 90)

ICUs nurses' responsibilities are various. In general, their job is to continuously monitor vital signs, acting as an advocate and providing life-sustaining treatment for the patient. Nurses also work as a close bridge with the patient's relatives concerning any changes in the patient's conditions (Fry 2011, 58 – 66). They are also to look for information from different reliable resources related to the background of the patient to support the treatment process and provide needed information to other involved healthcare professionals (Kleinpell et al. 2008).

Nursing requirements in critical care are high, including high professional skills, wide knowledge base and good experiences in dealing with critical condition patients. It requires the ablity to act and decide decisely in case of unpredictable situations, the ability to communicate with colleagues, relatives and patients and the abilities to catch up with updated medical technologies. The working environments are challenging physically and mentally, in which critical and bustling settings can create huge stress both for nurses and patients (Goodarzi et al. 2015).

Currently there are no clear standards towards nursing competency assessment in ICUs. Mostly assessment is based on opinions rather than research-based method. Therefore, a standard tool of evaluation is urgently needed according to national protocols and instructions. (Chang et al. 2014, 121 – 125)

In recent years, critical care nursing is expecting rapid and demanding changes. The nature of intense work that nurses encounter every day in their working places; the rising work loads with its parallel high responsibility; the increasing demand of technologies and knowledge; the shortage of nurses are putting high pressure on nurses and the management board. In spite of that, many ICUs nurses find those challenges stimulating and a great chance for them to further develop their career path (Kluwer 2013).

In Finland, nursing program is provided by various universities of applied sciences across the country. There is currently no post-education specialized in critical care nursing. In the curriculum of those nursing programs, the students are equipped with basically general nursing knowledge and clinical skills rather than emphasizing on specialized fields or specialities. Therefore, many students seem to lack the opportunity of studying focusedly on what they are interested. The chance to practically work and study in ICUs mainly comes from practical trainings in the ICUs. (Lakanmaa 2012)

5.2 Cardiovascular monitoring in ICU

5.2.1 Electrocardiographic monitoring

Electrocardiographic (ECG) first came into practice in hospital in 1963. As simple as it may be, the primary purpose of the introduction is to identify arrythmia in coronary care unit (CCU) (Kreso et al. 2015, 319 – 322). In spite of that, cardiac monitors nowadays are being utilized widely from ICUs, operating theatres, specialized wards and external settings such as: ambulances or monitoring clinics. The global development of technology has a great impact on medical technology. A practical proof of that is over the period of more than 50 years since introduction, ECG monitors are being used to diagnose not only the patient’s basic heart rates and rhythm like before, but also detect the complex dysrhythmias, myocardial ischemia, and even prolonged QT intervals. This is the achievement of the invention of computerized dysrhythmia detection algorithms, ST-segment monitoring software, multilead monitoring systems and 12-lead ECGs (Drew, Califf, Funk et al. 2014, 2721 – 2746).

5.2.1.1 Cardiac monitoring devices

In practices, there are two common monitoring systems: continuous hard-wire systems and telemetry monitoring systems.

- Hard-wire monitoring systems

  This type of monitor has been used widely in ICUs which connects the patient directly to the cardiac monitor through ECG cables. Hence, the patient should be at the bedside during monitoring course. Cardiac data will be recorded at the display screen as well as monitor centres. Although working as an electricity-based monitor, complications caused by that are unlikely to happen. (Hravnak et al. 2008, 1300 – 1308)

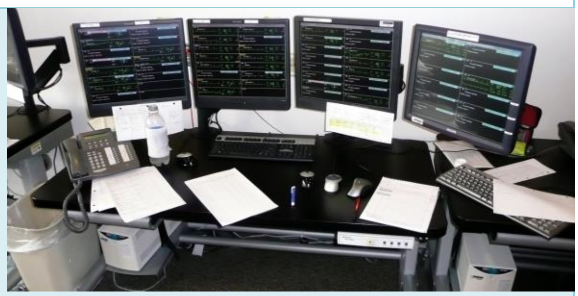
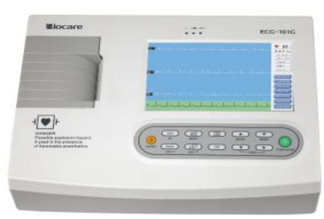
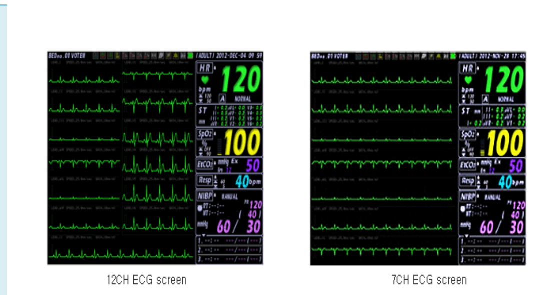
- Telemetry monitoring systems.

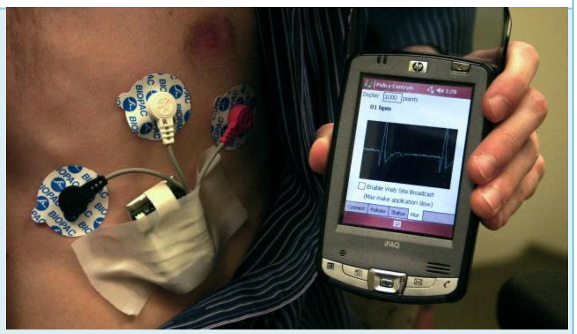
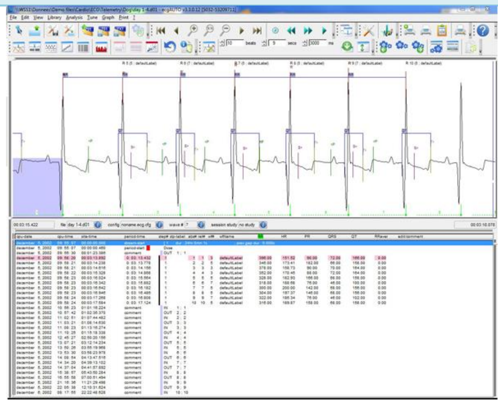
  As opposed to the previous systems, telemetry monitoring systems are known as “wireless”, as they have no direct wire connection devices between the patient and the display screen. In telemetry monitoring systems, a battery transmitter plays the role of electrodes gathering. Subsequently, an oscilloscope wil receive the ECG information and display to the central screen at the bedside or recording station. (Zorzi et al. 2016, 6 – 11)

5.2.1.2 Display systems

The table below demonstrates some examples of the latest display systems, with some advanced features compared to the traditional ones.

Table 5. Cardiac monitoring display systems and examples (Huff 2012)

Display systems	Indication	Examples
Computerized storage	Dysrhythmias retrievals.	
Automatic chart documentation	Alarm activated / Preset intervals	
Expanded alarm systems	Variety of parameters	
Multilead or 12-lead ECG display	Complex dysrhythmia	
ST-segment analysis	Monitoring ischemic events	

Computerized systems with multifunctions : store, analyze, charts, data retrievals.	Aid in diagnosis and monitor the status trends	
Wireless communication devices	Provide data and alarms	
QT-interval monitoring	QT-interval monitoring	

5.2.1.3 Lead monitoring systems

According to Morton and Fontaine (2014, 270), all cardiac monitors use lead systems to retrieve the electrical information from cardiac tissues. Morton also supposed that each lead system includes a positive electrode, a negative electrode and a ground electrode. (Morton & Fontaine 2014, 270)

A standard ECG comprises of 10 leads connected to the patient (4 to limbs, 6 to the chest) and provide cardiac information under 12 electrical views of the heart (Sivaraman et al. 2015, 2 – 6). Although in hospital nowadays cardiac monitoring systems seem to vary greatly from place to place, in this thesis, however, only the three-electrode system and five-lead system are discussed.

a. Three-electrode system

Many research groups have preferred three-electrode systems than traditional 12-lead one due to its compact setting and conveniences. In case of ampulatory situation, the speed of action and the accuracy are first pritorities (Sungyoup 2009, 166-175). Positive electrodes, negative electrodes and ground electrodes are placed in the right arm (RA), left arm (LA) and left leg (LL) respectively. The figure below demonstrates how the leads are placed on the patient's body. An example of the electrodes movement current is Einthoven's triangle (figure 7). In figure 7, lead I, II, and III are known as the standard leads. When placed together over the chest, they are called Einthoven's triangle. (Abi-Saleh & Omar 2010, 33 – 38)

Lead I: LA - positive, RA - negative

Lead II: LL - positive, RA - negative

Lead III: LL - positive, LA - negative.

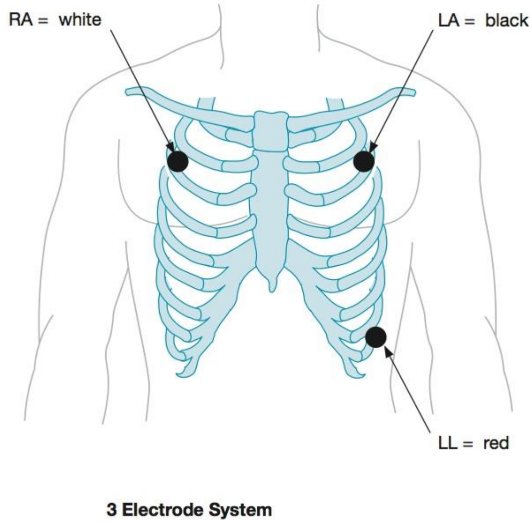


Figure 6. Three-electrode monitoring system. (LITFL 2016)

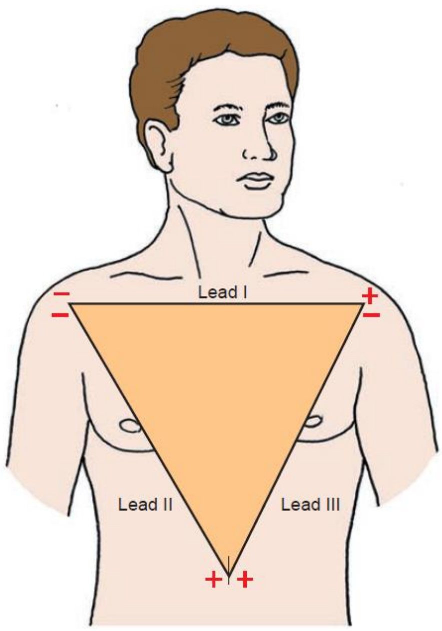


Figure 7. Einthoven's triangle (Morton & Fontaine 2014)

b. Five-electrode system

The five-electrode systems provide more variables than the three-electrode systems. In five-electrode system, every electrode is put on the limbs, and one on the chest (Figure 8). (Dash 2012, 251 – 260)

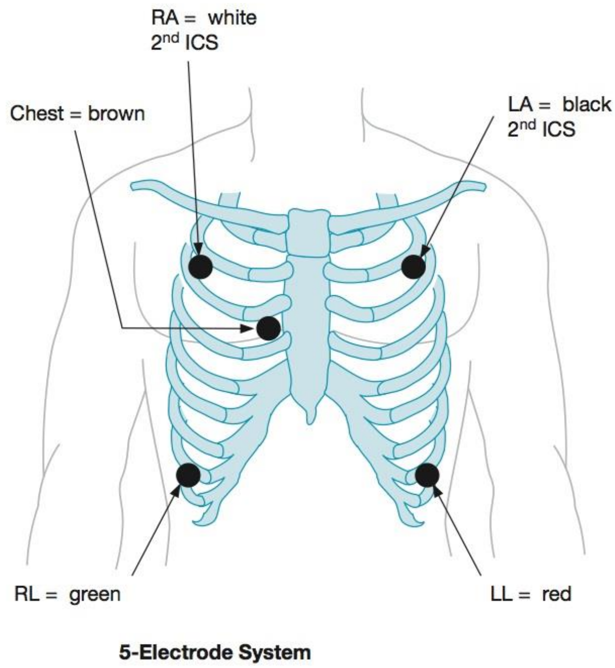


Figure 8. Five-electrode system (LITFL 2016)

5.2.1.4 Monitor observation

The primary purpose of all the electrocardiography systems is to produce precisely, timely cardiac information to the monitoring centres. The ability of interpretating the cardiac data requires appropriate, sufficient personnel training. However, it could not be acquired in practice due to insufficient financial ability. In certain ICU settings, there are available trained physicians whose tasks are intepretating cardiac data and delegate the intervention actions to nurses. Understanding those data could even save the patient's life in time. Therefore, continuos observation and precise interpretation is one most important task in cardiac monitoring. (Gazarian et al. 2015, 151 – 159)

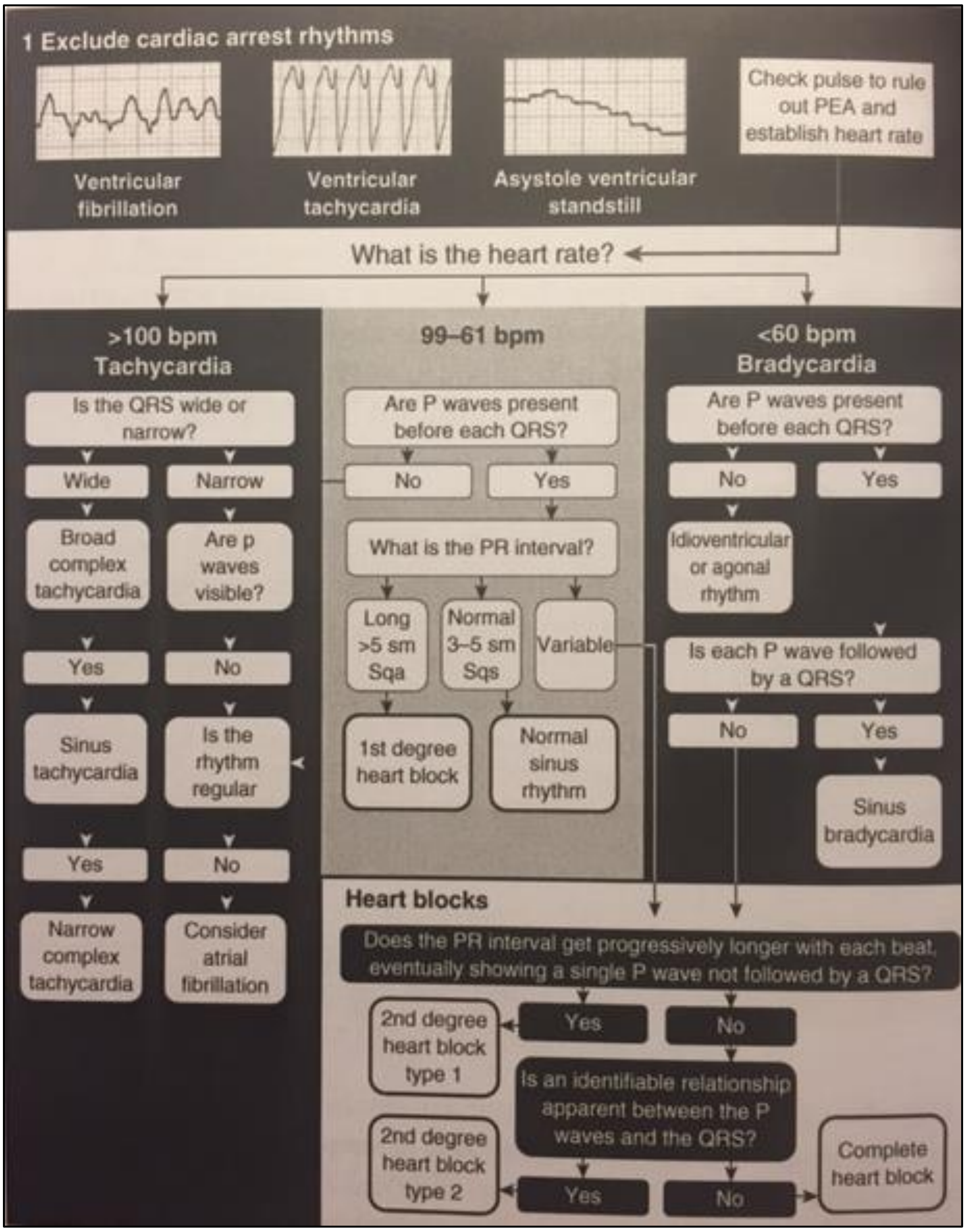


Figure 9. Basic rhythm analysis chart (Mulryan 2014, 168)

5.2.2 Hemodynamic monitoring

Besides electrocardiographic monitoring, hemodynamic monitoring is another common measures to evaluate cardiac status. By hemodynamic monitoring, the patient‘s intracardiac, intravascular pressures, and cardiac function will be evaluated at the care unit (Miller-Keane 2016).

Why hemodynamic monitoring is used collaterally with ECG? The purpose is to optimize cardiac function, minimize cardiovascular dysfunction and evaluate the patient's response to treatment. Hence, the primary aim of hemodynamic monitoring is to ensure sufficient oxygenation of tissues and organs. (Bigatello & George 2012, 219 – 225). Figure 10 shows the perfusion triad in hemodynamic monitoring.

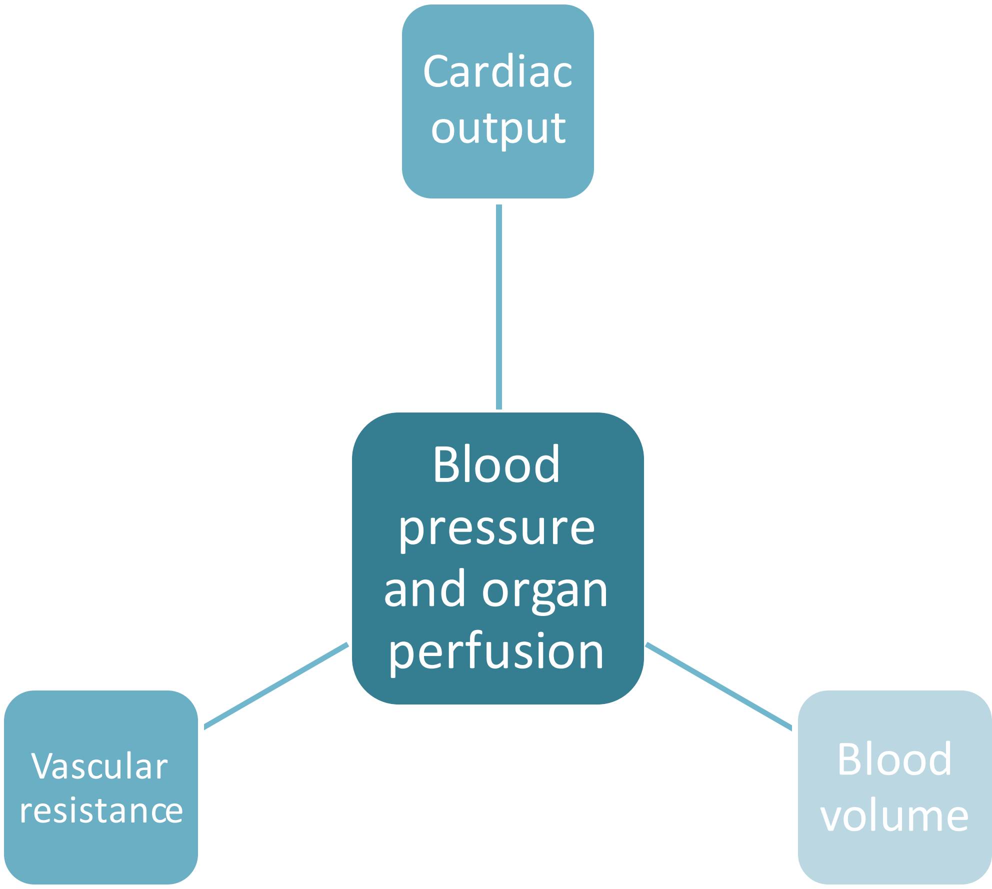


Figure 10. The perfusion triad (Mulryan 2014, 125)

In order to integrate hemodynamic information to critical care, Darovic (2012) has mentioned the required competences in critical care nursing:

- Cardiorespiratory anatomy and physiology
- Monitoring system components to measure cardiac and vascular pressures and cardiac output.
- Rationales for interventions directed toward enhancing cardiac output, oxygen delivery, and oxygen consumption
- Potential complications

- Differences between physiological and mechanical changes or monitoring system problems.

5.2.3 Pressure monitoring system

Basically, equipments used in invasive blood pressure monitoring include a hollow tube catheter, a fluid-filled pressure monitoring system comprised of flush solution, an IV tubing with drip chamber, a non compliant tubing, stopcocks, a flush device, one or more transducers, and a monitor that amplifies and displays the pressures and wave forms (Jacq et al. 2015) (Figure 11)

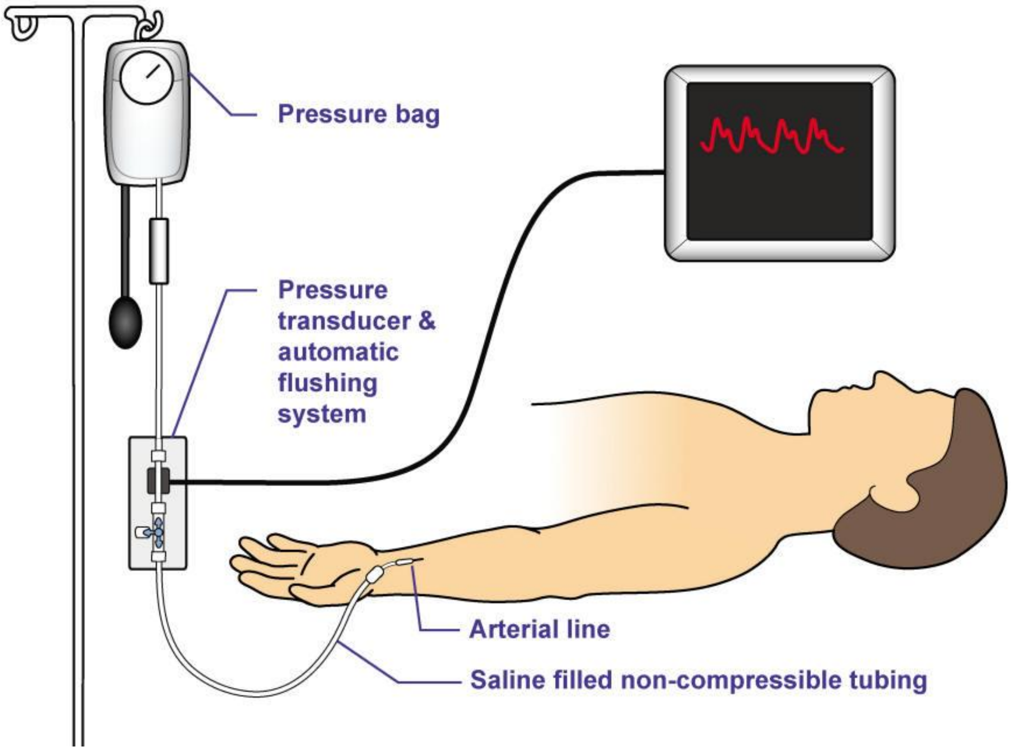


Figure 11. Simplified illustration of pressure monitoring system. (Gormersal 2016)

5.2.4 Arterial pressure monitoring (MAP)

Mean arterial pressure (MAP) monitoring are formed by inserting an intra-arterial catheter to the pressure monitoring system. Most of the time, the arterial catheter is inserted to the radial arteries, brachial arteries or femoral arteries. This activates the continuity of systematic arterial blood pressure monitoring. At the same time, blood samples can be withdraw immediately from a stopcock when necessary. (Headley 2013, 179 – 187)

The MAP calculation is as follow:

MAP = Diastolic pressure + ½ Pulse pressure

The difference between systolic and diastolic pressure is the pulse pressure. This value reflects the likelihood of stroke volumn from the ventricle (Magder 2007).

The figure 12 below demonstrates the Allen's test to obtain the arterial sites.

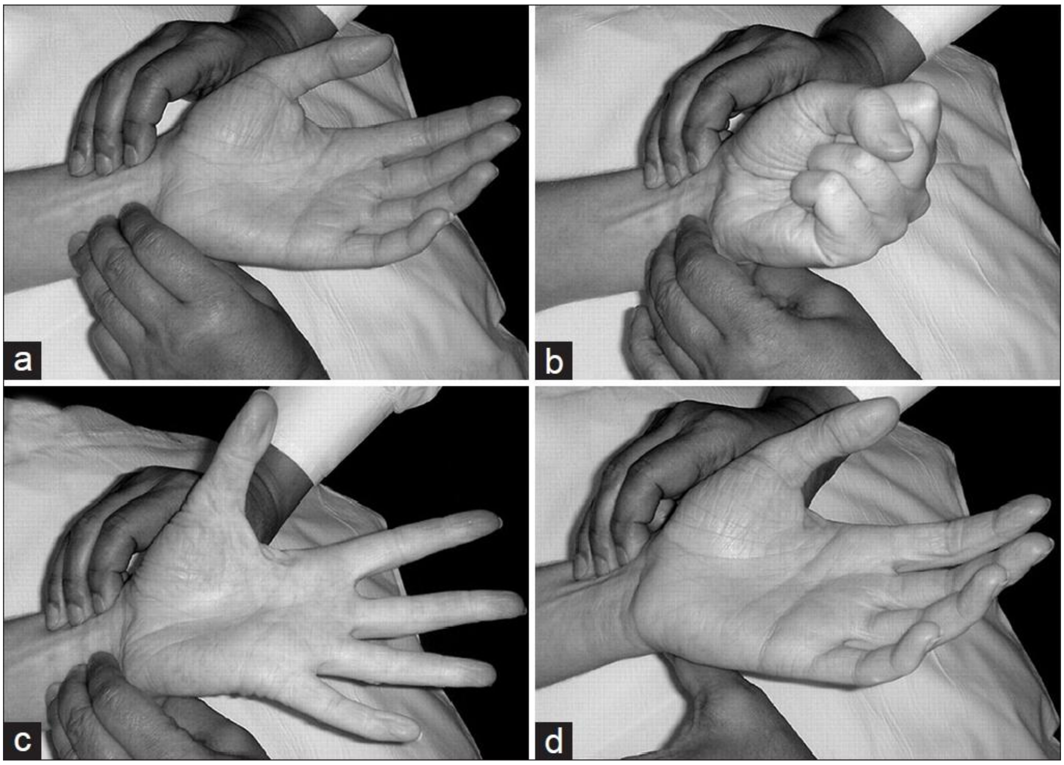


Figure 12. The modified Allen's test (Tanzilli et al. 2015, 3006 - 3011)

a. The radial and ulnar palpation

b. Fist

c. Open Fist

d. Release of the ulnar artery pressure.

5.2.5 Central venous pressure monitoring

Central venous pressure (CVP) is to measure the blood pressure in the right atrium, which is done with the help of a central venous catheter. As the result, it provides data about intravascular blood volume, right ventricular end-diastolic pressure (RVEDP) and right ventricular function (Abbasian et al. 2015). In addition to that, CVP also indirectly measures left ventricular end-diastolic pressure (LVEDP) and function. Unstable high or low CVP-figure is highly associated with alteration in intravascular volume status or ventricular function. (Sondergaard, Parkin, Aneman 2016). It should also be noticed that CVP-catheter insertion might brings along serious complications such as infection, thrombosis, or air embolism. (Chen et al. 2016)

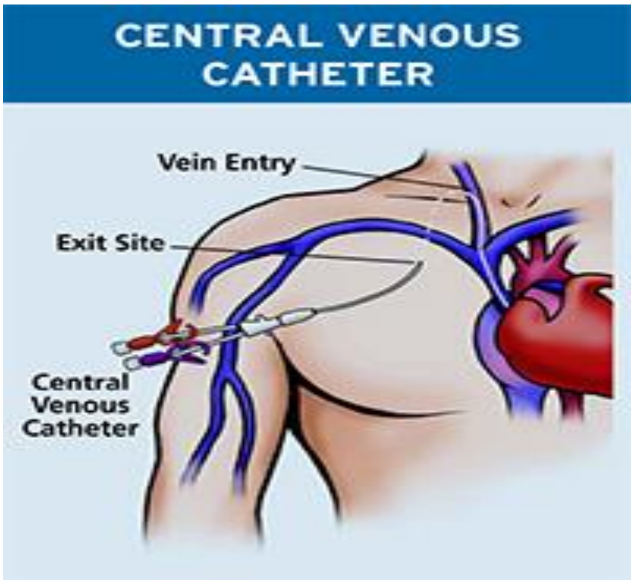


Figure 13. Central venous catheter – Entry and exit site (Kidneyfund 2016)

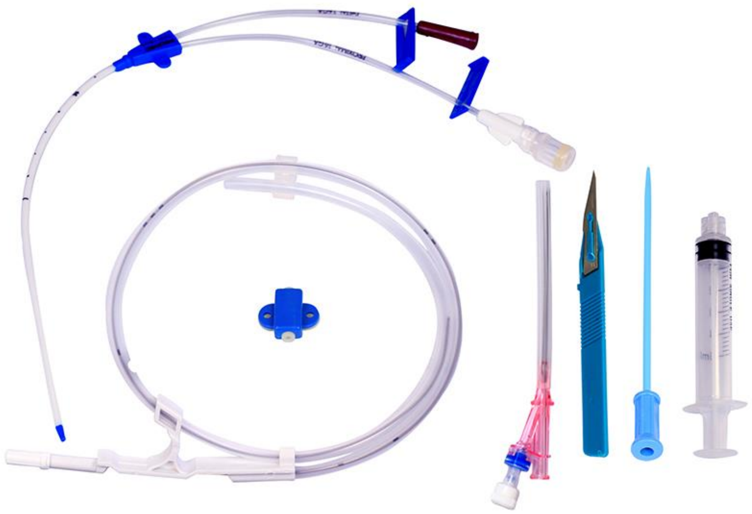


Figure 14. Example of central venous catheter equipments (Polymedicure 2016)

5.2.6 Pulmonary artery pressure monitoring

Similar to PVC, the pulmonary artery pressure (PAC) system allows the assessment of right ventricular function. Moreover, pulmonary vascular status and left ventricular function are also been evaluated. Main measurements using PAC are right atrial, right ventricular, and PA pressures, as well as pulmonary artery wedge pressure (PAWP) (Müller et al. 2016, 83 – 91)

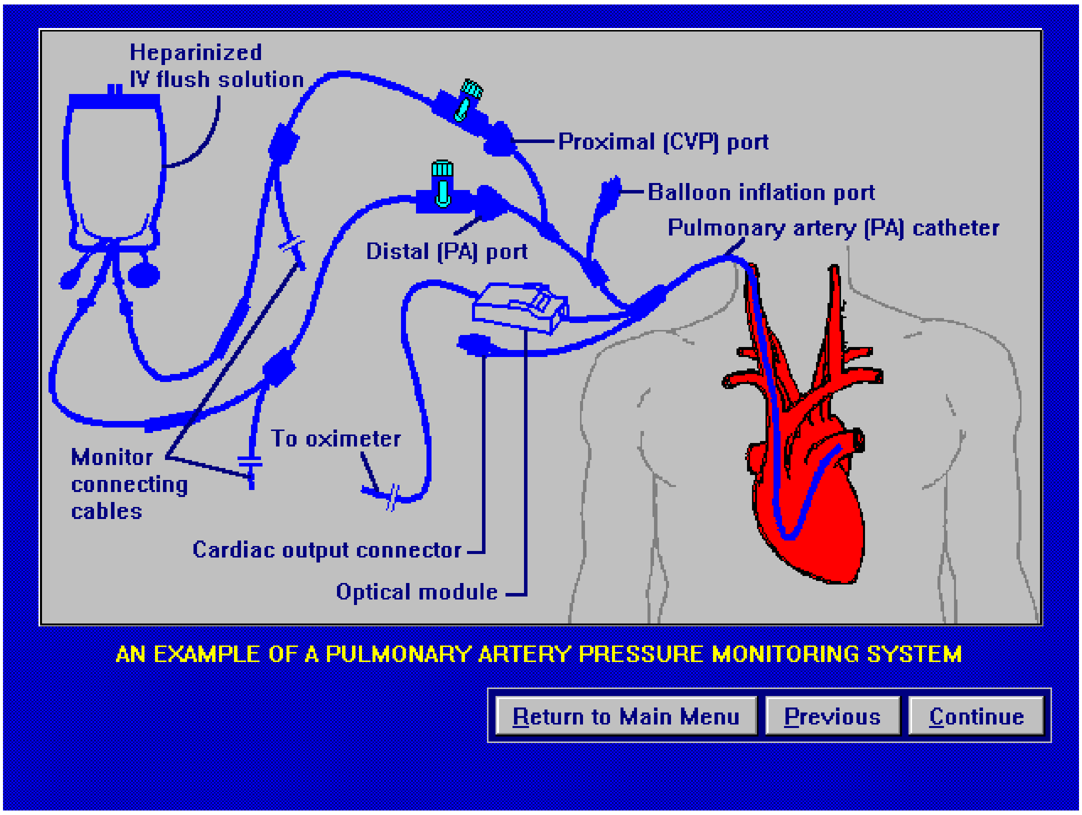


Figure 15. Example of pulmonary artery pressure monitoring system (cssolutions 2016)

5.3 Respiratory monitoring in ICU

5.3.1 Respiratory anatomy and physiology

5.3.1.1 Respiratory system anatomy

The function of the respiratory system is to exchange gases between the body and the external invironment. The respiratory system, moreover, maintains many other fuctions such as acid-base balance regulation or wasted materials' filtration (Preedy & Prokopovich 2013, 3 – 12). With the help of respiration and blood circulation, our body thrives to ensure the efficient oxygen concentration in the blood, which plays a crucial role in promoting the metabolism (Kosovskaya 2015).

The respiratory system is complex. In general, the anatomy of the respiratory system includes the thorax (the major structure of the whole respiratory system), the conducing airways, the respiratory airways, the lung circulation and the pulmonary lymphatics (Preedy & Prokopovich 2013, 3 – 12).

In details, the following table shows the components of each above-mentioned structure:

Table 6. The respiratory system's components (Preedy & Prokopovich 2013, 3 – 12)

The thorax	- Thoracic cage - Muscles of ventilation - The lungs - The pleural space - The mediastinum	-
The conducting airways	- Nasopharynx - Oropharynx - Trachea - Bronchi - Bronchioles - Terminal bronchioles	-
The respiratory airways	- Respiratory bronchioles - The alveolar ducts - The alveolar sacs	-
The lung circulation	- Bronchial circulation (blood-> airways) - Pulmonary circulation (gas exchange)	-

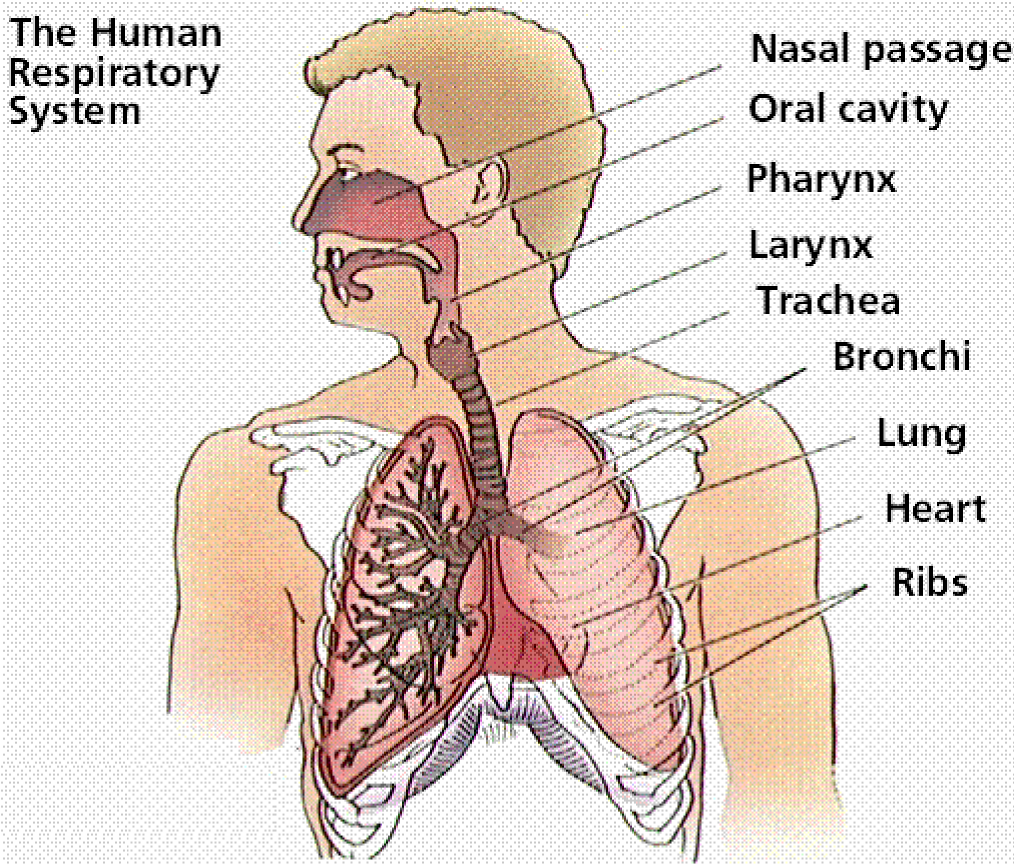


Figure 16. Structures of the respiratory system (Farabee 2016)

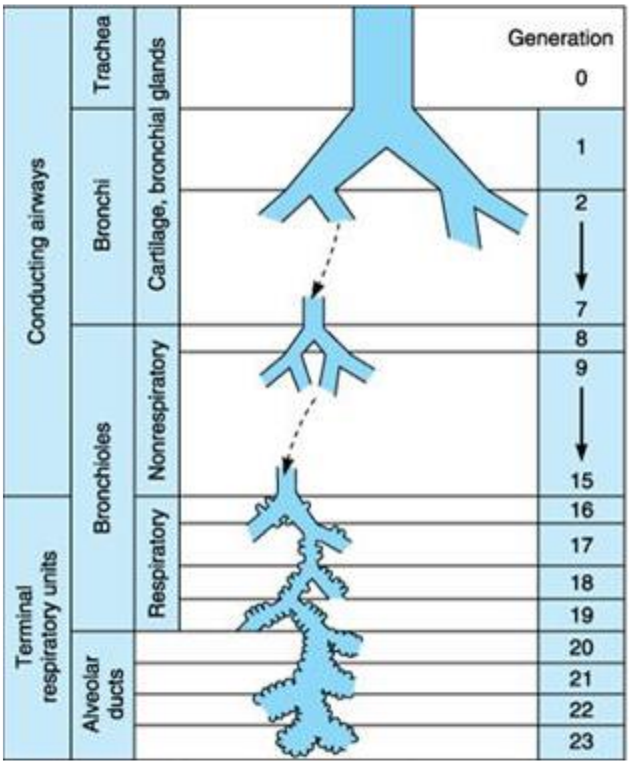


Figure 17. Conducting airways and respiratory airways (McPhee & Ganong 2016)

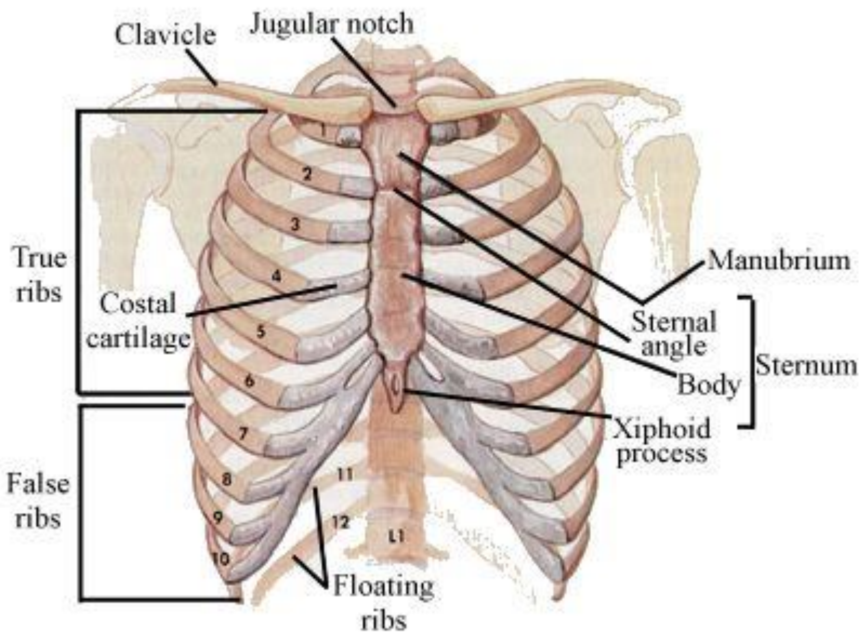


Figure 18. Thoracic structure (Atlas of Human Anatomy 2008, 149)

5.3.1.2 Respiratory system physiology

The respiration's main job is to provide O_2 to our body's tissues and remove CO_2. This can be achieved through three processes: ventilation, diffusion and transport (O_2 and CO_2 in the blood to the cells and vice versa) (Johnson 2009).

Ventilation includes inhalation and exhalation. With the help of respiratory muscles and changes in pressures (airway pressure, intrapleural pressure, intra- alveolar pressure, intrathoracic pressure), the chest cavity can be expanded and contracted to allow movement of air in and out of the lung. Air moves through the upper airways, down the lower airways into the respiratory bronchioles and the alveoli inside the lung.

Diffusion process means the exchange of O_2 from the alveoli to the pulmonary capillaries and CO_2 from the pulmonary capillaries to the alveoli. This happens after the alveoli have been fully ventilated with fresh air from the first process. The bronchial trees have various sub-branches which divide into terminal bronchioles, ending up with alveoli. Millions of alveoli in our lungs are, consequently, in charge of the gas exchange process. Those alveoli are located closely with the capillaries (full of depxygenated blood), which allows the gas exchange process to happen accross the alveolar-capillary membrane.

(John B 2015)

The alveoli and capillaries locations can be seen in figure 19 amd the diffusion process can be clearly illustrated in figure 20.

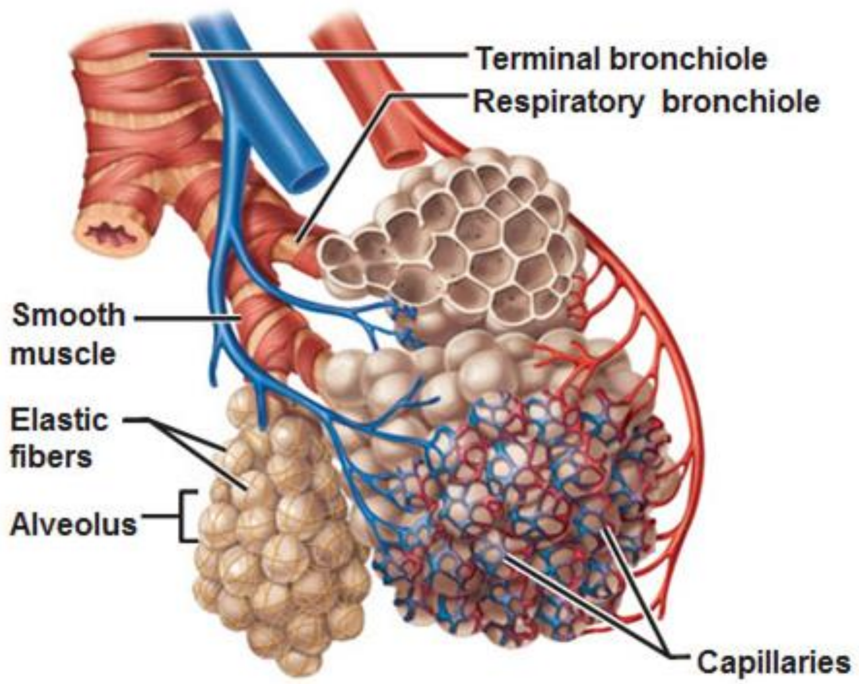


Figure 19. Alveoli and pulmonary capillaries (Imonus 2016)

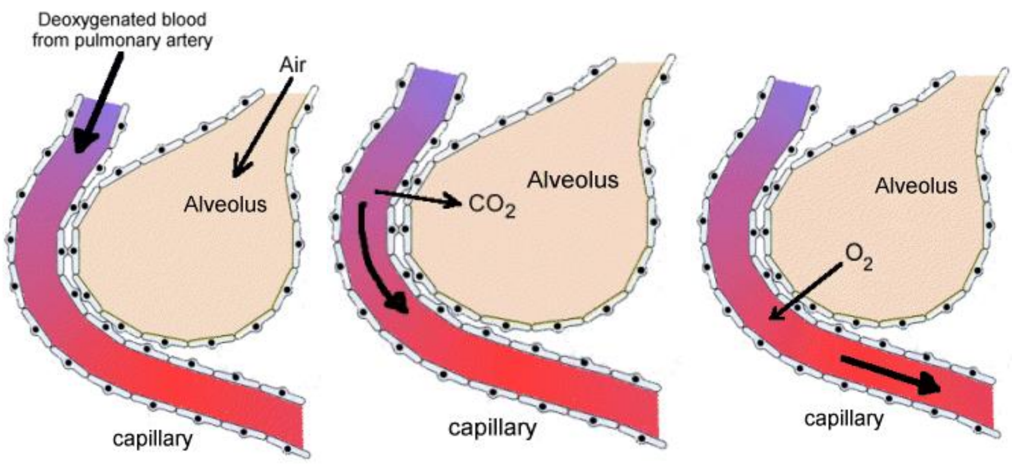


Figure 20. Gas exchange process (Hall 2011)

5.3.2 Patient assessment

Initial patient assessments and physical examination play a huge role in evaluating the progress of treatment and should be made before, during and after medical interventions (Morton & Fontaine 2014). The clinical history of the patient mainly consists of: chief complaint, present illness, past medical or surgical record, family history, personal and social history and review of systems. According to Camporota & Rubulotta (2012), thorough information concerning lung diseases' risk factors is to be collected, including:

- Smoking history (past smoking, current smoking, number of packages, cessation, passive smoking)
- Sleeping disorders concerning breathing
- Environmental risk factors concerning lung diseases (hazardous inhalation of agents, infectious lung disease exposure)
- Patients with immunocompromised status
- Other related history diseases such as systemic rheumatic diseases, motor neuron diseases, neuromuscular junction diseases, immune- mediated neuropathies.

Common signs of respiratory dieases include coughing, sputum and haemoptysis. The patient can usually manifest shortness of breath, pain in the chest or cyanosis (patients with anaemia hardly shows cyanosis) (Camporota & Rubulotta 2012).

Physical examination is to collect needed data that are obtained through inspection, palpation, percussion and auscultation (Bickley et al. 2007). In inspection process, some factors are taken into consideration to notice signs of respiratory distress. Those factors include skin colors, signs of labored breathing, the size of the chest from front to back (the anterior-posteriaor diameter of the chest), signs of previous chest deformities, the patient's posture, position of the trachea, the respiratory rate as well as respiratory efforts, the the thoracic expansion, the duration of inspiration and expiration (Pryor & Ammani. 2008). Moreover, chest investiations are also used as an important part of respiratory examination. Being used nowadays are are radiological techniques and fibre optic techniques (Camporota & Rubulotta 2012).

5.3.3 Respiratory monitoring

The common protocols for respiratory monitoring focus mainly on gas exchange (oxygenation) and ventilation. The purpose is to to ensure four categories that make up the respiration: ventilation, gas exchange, gas transport and control of ventilation (Becker et al. 2009). Ventilation (breathing) basically means the movement of gas between the external environment and the pulmonary alveoli in the lungs whereas oxygenation refers to the oxygen content in our arterial blood. The oxygen content is dependent fully on efficient ventilation and perfusion of capillaries. Therefore, oxygenation and ventilation are fully related but those two processes are separate from each other (Becker et al. 2009).

Respiratory monitoring means comprehensive monitoring of lung functions with numeric and graphic values based on monitoring techniques. It includes intensive control of breathing and gas exchange. Breathing is calculated by means of respiratory mechanical values, respiratory patterns and respiratory rate. Gas exchange is calculated by analysis of oxygenation and analysis of carbon dioxide content (Ward et al. 2010, 54 – 57).

Therefore, a nurse’s responsibility during ventilation monitoring is to calculate respiratory rate and evaluate respiratory mechanics, the airway, respiratory movement, breath sounds to recognize any signs of respiratory distress (Junttila 2014)

In order to fully monitor respiratoring processes, different monitoring techiniques are utilized. They are used with different purposes, depending on the needed analysis of the patient’s situation. Those techinques are condensely demonstrated in table 10.

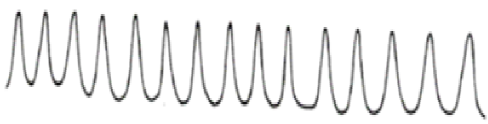
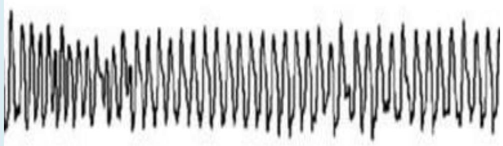
Table 7. Respiratory monitoring techniques (Brochard 2012)

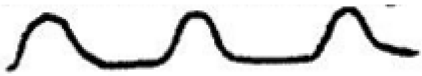
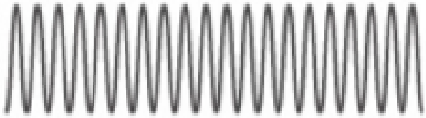
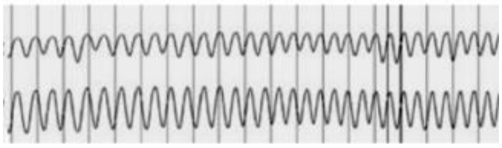
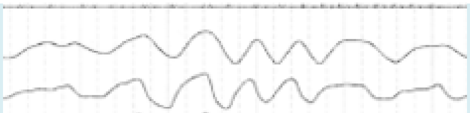
Monitoring technique	Continuous versus intermittent
Pulse oximetry	Continuous
Ventilator pressures	Continuous
Ventilator traces	Continuous
Respiratory mechanics	Intermittent
Pressure/volume curves	Intermittent
Work of breathing, pressure-time product	Intermittent
Extravascular lung water	Intermittent
Lung volumes	Intermittent
Electric impedance tomography	Continuous
Hemodynamic monitoring	Continuous or intermittent
Volumetric capnography	Continuous
Esophageal and transpulmonary pressure	Continuous or intermittent
Diaphragmatic electromyography	Continuous

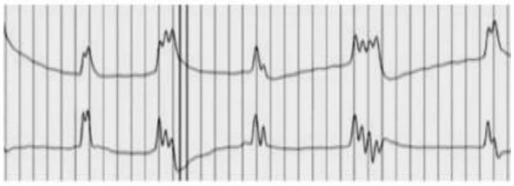
5.3.3.1 Ventilation

Understanding the respiration patterns (breathing patterns) can help nurses realize different signs of respiratory distress. The rate, depth, rhythm and characters of breath are important to the balance of respiration. The table below demonstrates different breathing patterns with their potential indications.

Table 8. Respiration patterns (Yuan et.al. 2013, 23)

Normal pattern: Regular, 12-20 breaths/min	
Tachypnea: Increased rate of breathing, >24 breaths/min. Rapid, shallow breathing *Indication*: Fever, respiratory insufficiency, alkalosis, pneumonia.	

Bradypnea: Decreased rate of breathing, <10 breaths/min. Low, shallow breathing *Indication*: Diabetic coma, respiratory depression, neurologic damage	
Hyper ventilation: Increased rate and increased depth *Indication*: Anxiety or pain, extreme exercise, fear, excessive use of salicylate, infections, pneumonia, congestive heart failure, disorders of central nervous system	
Kussmaul: Rapid, gasping, labored breathing, “air hunger” *Indication*: Diabetic ketoacidosis	
Hypoventilation: Decreased rate and depth, irregular pattern *Indication*: Excessive use of narcotics or anesthetics	
Cheyne-Stokes respiration: “periodic breathing”, alternative period of tachypnea and apnea *Indication*: Congestive heart failure, drug overdose, brain tumors, brain injuries, strokes, renal failure.	
Biot’s respiration: “cluster breathing”, irregular patterns followed by apnea periods *Indication:* Meningitis, brain damage	

Ataxic: Irregular of breathing with irregular pauses and varying depths	
Air trapping: Difficult in breathing out *Indicaition:* obstructive pulmonary disease	

5.3.3.2 Gas exchange

a. Pulse oximetry

Approximately 97% of oxygen content is attached to hemoglobin (Hgb) in red blood cells. The small remaining amount of around 2-3% is dissolved in plasma, producing partial pressure of oxygen in the arterial blood (PaO_2). Therefore, the amount of PaO_2 directly affects the amount of arterial oxygen saturation of Hgb (known as SaO_2). PaO_2 value is ranging 80-100mm Hg and SaO_2 is around 93-99% (Winslow 2007).

The relationship between PaO_2 and SaO_2 is demonstrated in the oxyhemoglobin dissociation curve below.

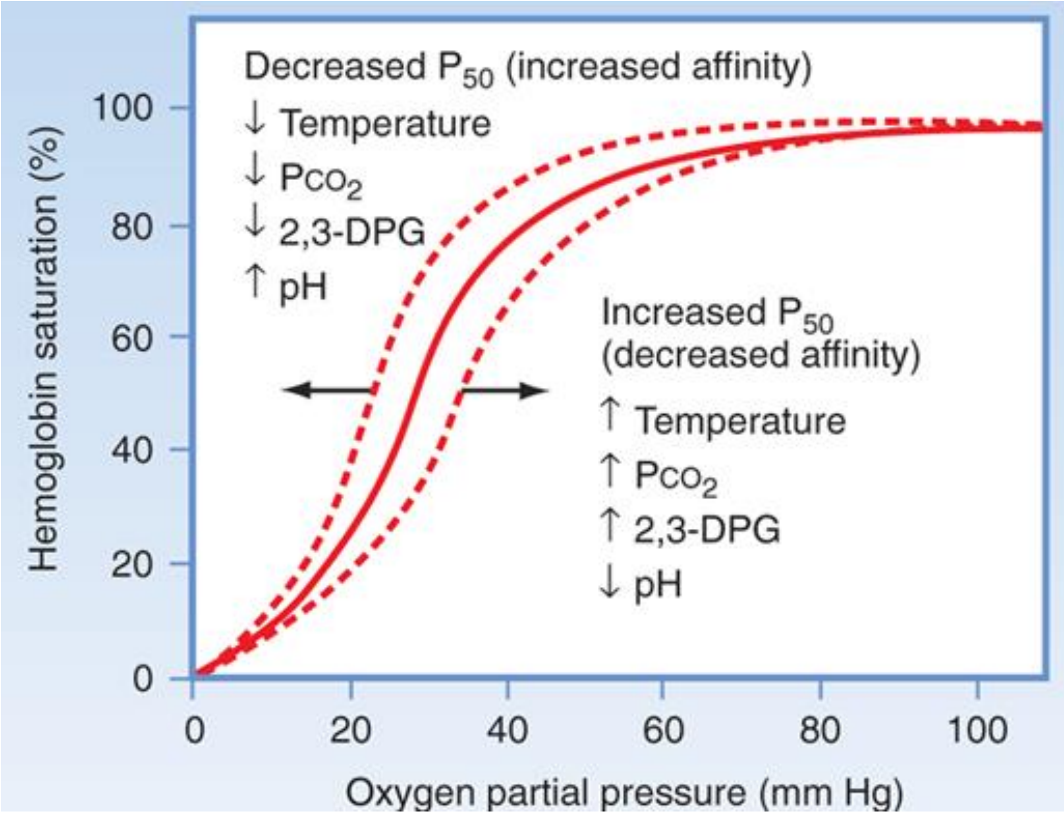


Figure 21. Oxyhemoglogin dissociation curve (Winslow 2007)

At the beginning part of the curve, the more oxygen partial pressures (PaO_2) increases, the more oxygen molecules are bound to hemoglobin (SaO_2 increases). This makes the curve to have a steep shape at first. The process continues until the oxygen molecules that can be bound to hemoglobin reach the maximum amount (hemoglobin becomes saturated with oxygen). The curve therefore becomes flat at the top, meaning that at this point, large change in PaO_2 only leads to small changes in SaO_2.

The term “affinity” refers to the hemoglobin capacity to bind with oxygen. In normal situation, when Hgb is 50% saturated with oxygen, PaO_2 stays at 26.6 mmHg and this is known as P_{50}. When affinity is affected by different reasons, the oxyhemoglogin dissociation curve will then move to left or right as illustrated in the figure. When the curve shifts to right, it means that more PaO_2 is needed to maintain 50% saturation, indicating decreased affinity. Vice versa happens when the curve moves to left.

The Hgb affinity is determined by pH (alkalosis or acidosis), carbon dioxide concentration ($PaCO_2$), temperature and phosphate compound (2, 3 - DPG)

(Varjavand et al. 2000)

Pulse oximetry is a non-invasive and continuous technique to measure arterial oxygen saturation of hemoglobin. The oxygen saturation measured by a pulse oximeter is called SpO_2 (Fahy et al. 2013)

Figure 22. Pulse oximeter (Fahy et al. 2013)

The pulse oximeter has light-emitting and light-receiving diodes that can identify oxy-generated and deoxygenated hemoglobin based on their light absorption. The pulse oximeter sensors are attached to finger, toe or earlobe of the patient. In case of infant, it is otherwise applied to the palm, arm, penis or foot for of the babies (Jones et al. 2015, 391 – 396). Even though pulse oximeter is a handful device to monitor oxygen saturation, it cannot be used to replace arterial blood gas monitoring (ABG). With ABG monitoring, a test in which blood is taken directly from artery at the wrist, both the oxygen amount in the blood and and the carbon dioxide amount are recorded where as with a pulse oximetry, only oxygen amount is measured. Pulse oximetry reading cannot be reliable in such case of vaso-constricting medications, intravenous dyes or in the case of shock, cardiac arrest and anemia (Jones et al. 2015, 391 – 396).

b. End-tidal carbon dioxide monitoring

End-tidal carbon dioxide ($ETCO_2$) monitoring is used to measure the CO_2 level in exhaled air that can be used for ventilation assessment. The monitoring contains capnometry and capnograph. Capnometry is known as the numeric value of $ETCO_2$ pressure at the end of exhalation, which normally ranges from 35-45mm HG. Capnograph is a waveform that represents the concrete amount of CO_2 present at each phrase of respiration (Singer & Webb 2009)

Those two are illustrated in the figures below

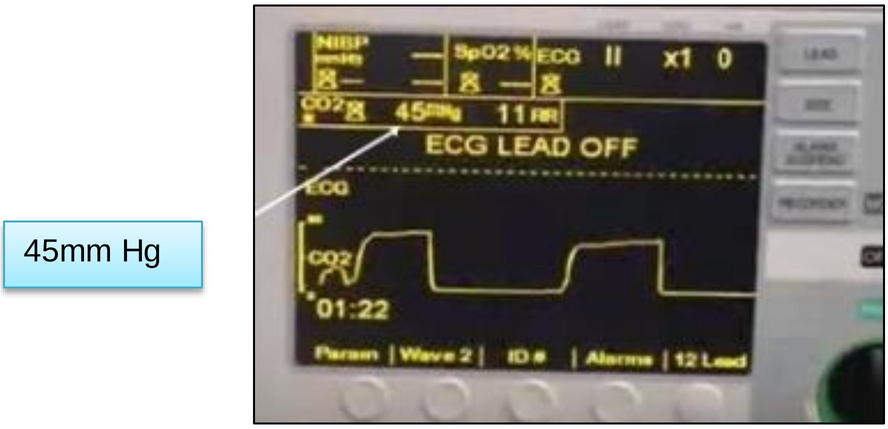


Figure 23. Capnometry value (Singer & Webb 2009)

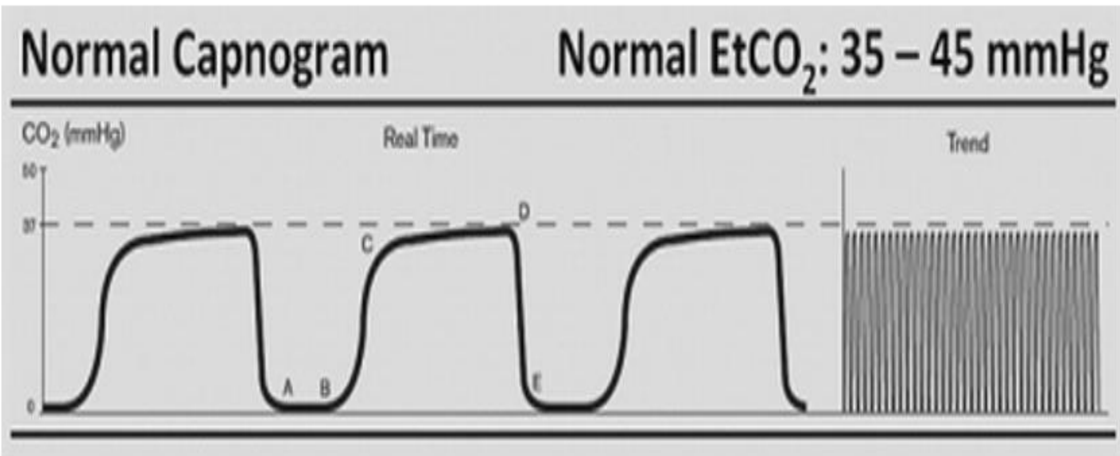


Figure 24. Capnography (Singer & Webb 2009)

The capnography basically includes four phrases, which are illustrated shortly as follows:

A-B: Baseline phase: Early phrase of exhaled breath

B-C: Expiratory upstroke phase: CO_2 is exhaled from the lung

C-D: Plateau phase: Exhalation of alveolar gases

D: ***$ETCO_2$ value: CO_2 level at the end of exhalation***

D-C: Inspiratory downstroke phase: Inspiration begins

Figure 25. Four phases of capnography (Singer & Webb 2009)

In short, while pulse oximetry is used in oxygenation analysis, end-tidal carbon dioxide monitoring provides constant feedback about ventilation (how CO_2 is produced, transported and eliminated efficiently) and it is a reliable tool for analyzing desease severity (Singer & Webb 2009)

c. Arterial blood gas

The arterial blood gas test (known as ABG test) is a test that is taken from arterial blood to identify pulmonary gas exchange (oxygen and carbon dioxide amount). Moreover, it can also be used to determine acid-base condition (Larkin & Zimmanck 2015, 343 – 357). In details, those indicators are determined based on ABG test:

Table 9. Arterial blood test and values (Larkin & Zimmanck 2015, 343 – 357)

pH	Hydrogen concentration in blood Normal value 7.35-7.45
PaO_2	Partial oxygen pressure. Normal value 80-100mm Hg
$PaCO_2$	Partial carbon dioxide pressure. Normal value 34-45mm Hg
SaO_2	Oxygen saturation of Hgb. Normal value 93%-99%
Bicarbonate (HCO_3):	Normal value 22-26 mEq/L

Measuring O_2 in the blood: Oxygenation is calculated by PaO_2 and SaO_2 using ABG test. As already mentioned in the pulse oximetry part, a large amount of oxygen binds to hemoglobin and a small amount dissolves into plasma. The normal value for PaO_2 is ranging from 80-100mm Hg and the normal value for SaO_2 is 93%-97%

Oxygen dissolved in plasma (PaO_2): O.3mL/100mL blood

Oxygen saturated haemoglobin (SaO_2): 19.4mL/ 100mL blood

Total oxygen in blood: 19.7 mL/100mL blood

Figure 26. How oxygen is carried in the blood (Larkin & Zimmanck 2015, 343 – 357)

Measuring pH in the blood: The pH is the measurement of hydrogen concentration in the blood. The normal value of pH is 7.35-7.45. When hydrogen icons increases, leading to a fall in pH value, the result would be academia (the blood is too acidic). Vice versa, when hydrogen icons decreases, pH value will increase, leading to alkalemia (blood is too alkaline) (Singer & Webb 2009).

Measuring CO_2 in the blood: Ventilatory function of the lung is responsible for removing CO_2. The $PaCO_2$ is the partial carbon dioxide pressure in the arterial blood. $PaCO_2$ value ranges from 35-45mm Hg. In case of hypoventilates, CO_2 increases and $PaCO_2$ increases (>45mm Hg), resulting in respiratory acidosis. In case of hyperventilates, CO_2 decreases, $PaCO_2$ decreases (<35mm Hg), leading to respiratory alkalosis.

Respiratory acidosis is the condition in which $PaCO_2$ value is greater than 45mm Hg and pH value is less than 7.34. It fundamentally means that the lung is not cabable of adequately removing carbon dioxide, resulting in excessive CO_2 level and affecting the pulmonary function.

Respiratory alkalosis is the condition in which $PaCO_2$ value is less than 35mm Hg and pH value is greater than 7.45. This means that the lung is excessively removing CO_2 from the serum.

(Singer & Webb 2009)

Measuring bicarbonate in the blood (HCO_3): HCO_3 main duty is to regulate pH level. Its normal value ranges from 22-26 mEq/L. If HCO_3 > 26mEq/L it will result in metabolic alkalosis. If HCO_3 <22mEq/L, metabolic acidosis will happen.

Metabolic acidosis is the situation when HCO_3 < 22mEq/l and pH < 7.35. It will lead to excessive non-volatile acids production. Metabolic alkalosis is the situation when HCO_3> 26mEq/l and pH >7.45. It results in excessive nonvolatile acids loss.

(Singer & Webb 2009)

d. Mixed venous oxygen saturation

Mixed venous oxygen saturation (SvO_2) represents the percentage of O_2 left in the venous blood after supplying to all the tissues of the body except the head. It helps evaluate the end result of O_2 consumption and delivery. Usually a blood sample is taken from the pulmonary artery catheter (PAC). Normal value of SvO_2 is 60%-80%, which means that oxygen supply and demand balance is adequately met (Ward et al. 2010, 54 – 57). There are different components in getting the oxygenated blood to the patient's tissues. Figure 27 below explains in details SvO_2 as part of the process.

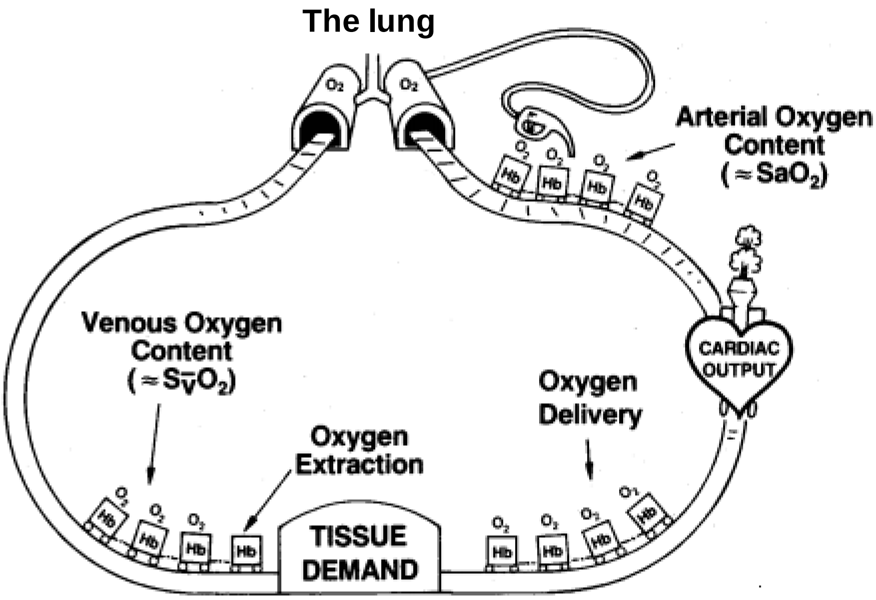


Figure 27. Mixed venous oxygen saturation (Edwards Lifesciences 2015)

Oxygenated hemoglobin molecules in the blood start to transport from the lung, with the help of heart pumping (cardiac output), flows to supply oxygen to reach the tissue demand. Not all the oxygen, howerver, is consumed by the tissues and the unused oxygen returns to pulmonary capillaries. This unused amount of oxygen in the venous blood is defined as SvO_2. The total amount of oxygen consumed to the issues is, therefore, calculated as follows:

Oxygen consumed to issues= Amount of oxygen carried to tissues (arterial oxygen delivery) – amount of unused oxygen that returned (venous oxygen delivery).

(Edwards Lifesciences 2015)

Low SvO_2 value can be the result of:

- Oxygen supply decrease (due to low hemoglobin, hemorrhage or low cardiac output)
- Oxygen use increase (demand of oxygen increases due to pain, stress or seizures, etc.)

Fixing low SvO_2 can be done by increasing oxygen supply (blood transfusion or cardiac output increase)

High SvO_2 value can be the result of:

- Oxygen supply > oxygen demand
- Demand decreases (due to hypothermia or anesthesia)

(Beest et al. 2008)

5.3.4 Respiratory therapy techniques

5.3.4.1 Oxygen therapy

Different diseases such as asthma, pneumonia, COPD or traumatic conditions (pneumothorax, hemothorax) or surgical actitivies (pneumonectomy, lobectomy) can lead to impair of the respiratory function, resulting in hypoxemia (the condition of low oxygen in blood level). Oxygen therapy, therefore, is crucial in supplying supplemental oxygen to maintain cellular functions. Moreover, oxygen therapy can also release the workload burden for breathing and cardiac work (Truwit & Epstein 2011, 3 – 31). The purpose of oxygen therapy is maintaining a stable SaO_2 level and releasing respiratory distress (anxiety, breath shortness). Oxygen therapy requires continuous monitoring to achieve the desired goals and prevent any signs of complications (Masclans et al. 2015, 505 – 515).

Patient assessment is important in chosing methods of oxygen delivery, levels of oxygen delivered. Those assements include types of underlying diseases, counsciousness level, respiratory efforts, vital signs, skin and nails colors and other numeric indicators such as SaO_2, ABG test results or labra data (JBTS 2015)

Basically, there are high-flow and slow-flow system of oxygen delivery. Low- flow oxygen devices provides oxygen at flow rate from 1-10L/min, which is less than inspiratory volume of the patient (with the condition of patients' normal respiratory patterns, rates and ventilation volume). High-flow oxygen device can provide oxygen at flow rate of 1-35L/min (2-3 times higher than the patient's inspiratory volume) (Singer & Webb 2009). The principles for oxygen therapy is to maintain SaO_2 between 92%-98% and high flow, high O_2 concentration should be provided in case of acute dyspnoeic or hypoxaemic until ABG analysis are done (Singer & Webb 2009).

Oxygen delivery devices are chosen based on the desired FiO_2 (the actual fraction of inspired oxygen) (Blake et al. 2014, 119 – 125). Those devices are demonstrated as follows:

a. *Standard nasal cannula:* Supply flow ranges from 1-5L/min and FiO_2 is from 24%-40% (ATS 2015)

Figure 28. Nasal cannula (EMP 2015)

b. *Venturi mask:* In need of accurate and constant FiO_2 regardless of tidal volume. Typical FiO_2 settings are 25, 31, 35, 40, 50% oxygen. It is useful for COPD patients and those with concerns of CO_2 retention (ATS 2015).

Figure 29. Venturi mask (EMP 2015)

c. *Simple facemask:* Is used in case of nasal irritation and mouth breather. Volume ranges from 100-300 mL. FiO_2 is 40-60% (ATS 2015).
d. *Non-rebreathing facemask with reservoir and one-way valve:* Is used in need of FiO_2> 40% or severe hypoxemia. It can provide the highest oxygen concentration (90%- 100%, flow rate of 10-15L/min). It consists of a facemask, oxygen bag and two valves. The purpose is to prevent room air from entraining (ATS 2015).

Figure 30. Non-rebreathing facemask (EMP 2015)

e. *Tracheostomy collar and T piece low-flow device:* Oxygen is delivered directly into endotracheal or tracheostomy tube. Flow rate is at the minimum level of 10L/min. The purpose is to deliver sufficent flow rate and prevent room air entraining (Hagberg et al. 2007, 502 – 531)
f. *High-flow warmed and humidified nasal oxygen:* The goal is to provide high level of oxygen with highest moisture possibilities that cannot be achieved through low-flow nasal cannula (Spoletini et al. 2015, 253 – 261).

Oxygen toxicity is seen as a real danger to the patient eventhough there remains controversial over the topic. Overdose or prolonged use of supplemental O_2 can cause damage to the lung, proteins, lipids and it is advised to avoid high FiO_2 whenever possible. Monitoring during oxygen therapy is therefore crucial to prevent any possible complications. O_2

analysis can be achieved continuously by observation, pulse oximetry and blood gas analysis (Truwit & Epstein 2011, 95-103)

5.3.4.2 Artificial airways

In many cases where oxygen therapy cannot maintain sufficient oxygenation and CO_2 removal, arficial airways or ventilatory support are needed. The benefits of artificial airways are clear, as they help to establish, protect and clear the patient's airway, supporting the ventilatory functions (Johnson et al. 2014, 58)

a. Oropharyngeal and nasopharyngeal airways

Oropharyngeal airway (OPA) is used only for unconscious patients. There are different sizes of OPA and determining the correct size for the patient is important. The appropriate airway is measured from the corner of the patient's lips to the bottom of the ear lobe or the angle of the jaw. Some complications concerning OPA are airway trauma caused by the process, or OPA removal due to intolerance from the patient. Patients with intact gag reflex can experience vomiting or aspiration and incorrect size of OPA can lead to risks of obstruction (QRS 2015)

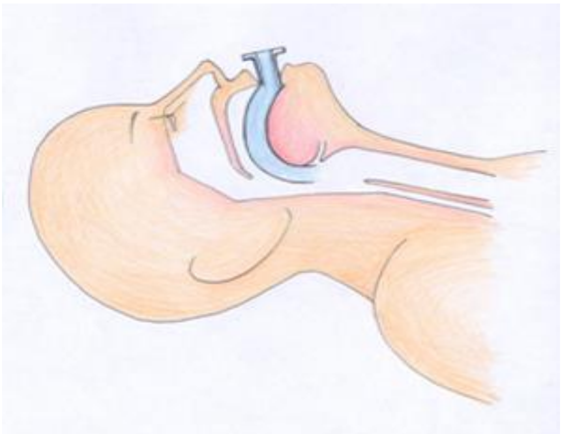


Figure 31. Oropharyngeal airway and insertion (QRS 2015)

Nasopharyngeal airway can be used for both responsive and unresponsive patients. It is advised when the oropharyngeal airway cannot be used and to those who often need nasopharyngeal suctioning.

Nasopharyngeal airways are produced in a variety of sizes. The correct size of nasopharyngeal airways is calculated from the tip of the nose to the earlobe. Complications of nasopharyngeal airway include airway trauma (epistaxis), injuries of the skull, gag reflex or incorrect size can reduce effectiveness (QRS 2015)

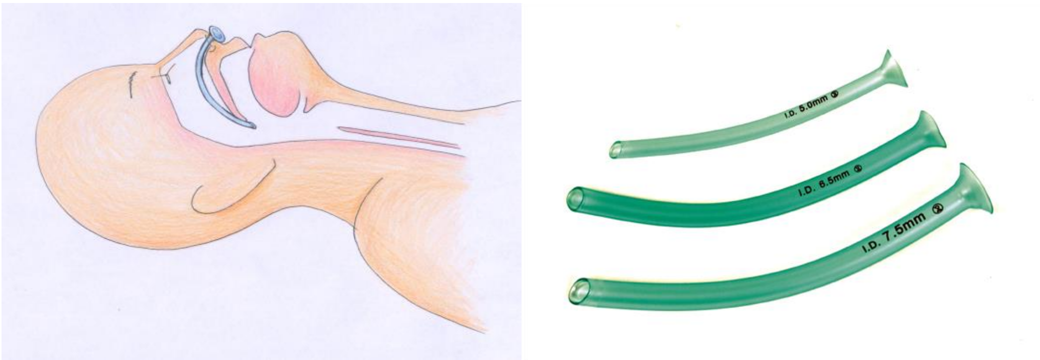


Figure 32. Nasopharyngeal airway and insertion (QRS 2015)

b. Endotracheal tubes

Endotracheal intubation (EI) is performed in case the patient is unresponsive and needs ventilation. This procedures helps maintain the open airway but also protect the airway from suffocation. Thanks to EI, the air can pass to and from the patient’s lung during respiration. Complications of EI include laryngospasm, hypoxemia or hypercapnia. It can possibly cause teeth fractures, oral bleeding, damage to trachea, lung injuries, hypertension or hypotension (Hardcastle et al. 2015)

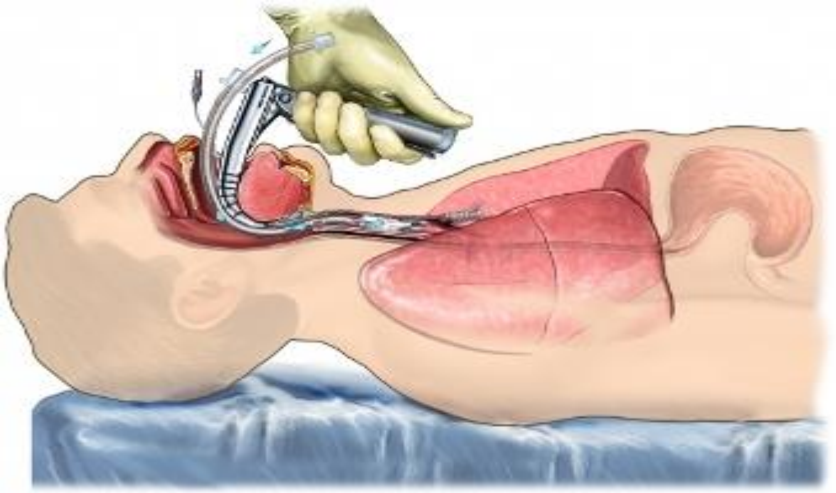


Figure 33. Endotracheal tubes and endotracheal intubation (NMM 2015)

5.3.4.3 Chest tubes

Chest tube insertion is used to drain air, blood or fluid out of the pleural space. Some indications for chest tubes include collapsed lung such as complex pneumothorax, pneumothorax on positive- pressure ventilation, hemothorax, large pleural effusion, empyema, chylothorax. Some chest tubes are placed as part of cancer treatment or post-surgical requirement. Complications of chest tube insertion are pain, infection, lung injuries, bleeding and incorrect placement of the tube can create damage to other organs nearby located (ATS 2015)

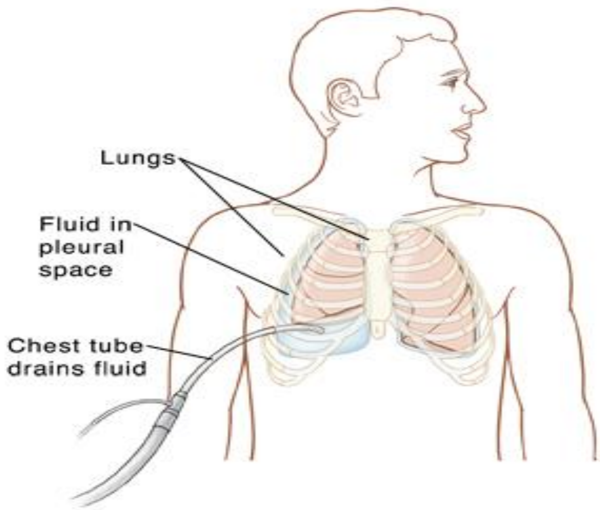


Figure 34. Chest tube insertion (MNH 2015)

5.3.4.4 Ventilatory support

Ventilatory supports are divided into non-invasive ventilation (NIV) and invasive ventilation. NIV is determined as the method of providing ventilatory support by facial masks or non-invasive ventilators through the upper airway. In invasive ventilation, in contrast, the patient will be intubated with tracheal tube, laryngeal mask or tracheostomy (which is why it is called “invasive”) (Truwit & Epstein 2011)

NIV is usually preferred in case of COPD with respiratory acidosis, hypercapnic respiratory failure or neuromuscular diseases. NIV are favoured for its benefits of reducing complications from intubation, reducing hospital stays and mortality. In spite of that, it cannot be used to replace needed invasive ventilation (Truwit & Epstein 2011).

In case the patient develops respiratory failure, more invasive mechanical ventilator supports are necessarily applied.Respiratory failure is the condition when sufficient respiration is not achieved based on the arerial blood gas analysis. The adequate respiration status requires indicators of pH> 7.25, $PaCO_2$ < 50mm Hg and PaO_2> 50mm Hg. Prolonged mechanical ventilation, however, poses different complications to the patient, namely ventilator-associated lung injury (VALI) and ventilator-induced lung injury (VILI). Those complications can be, for example, barotrauma, valutrauma, oxygen toxicity, decreased cardiac output pneumonia and auto PEEP. Those potential lung damages can be controlled by maintaining plateau pressures less or equal to 30cm H_2O, maintaining PEEP, reducing FiO_2 to 50%. Moreover, the patient VT should be kept at 5-6mL/kg of body weight (Hughes et al. 2013, 466 – 471).

a. Ventilarory support equipments

There are different ventilator support systems, including manual resuscitators and mechanical ventilators.

Manual resuscitation is known as bag-valve device illustrated in figure 35:

Figure 35. Bag-valve device (EMP 2015)

Mechanical ventilators are devided into negative-pressure ventilators and positive-pressure ventilators. Negative-pressure ventilator is recognized as “iron lung” whose function is to enlarge the thoracic cage by negative pressure, thus air can move into the lung. Negative-pressure ventilators are used for those patients who are not in use of artificial airways. Nowadays, negative-pressuer ventilators are not favored due to its huge structure and uncomfortable settings. Positive-pressure ventilators, therefore, take its place. Positive-pressure ventilators are divided into volume ventilators, presussure ventilators and high-frequency ventilators. (Grasso et al. 2008, 412 – 418).

Figure 36. Positive-pressure ventilators system (Baura 2012, 217 – 236)

b. Ventilator setting

- Trigger: Is what makes the ventilator deliver the breath. Sensitivity setting should be set appropriately, neither too high nor too low.
- Respiratory rate: Number of breaths/min the ventilator delivers.
- Tidal volume: The air amount coming in with each breath.
- PEEP: Positive end-expiratory pressure that helps prevent alveolar collapse.
- Flow rate: Determins how fast tidal volume is delivered. In case of COPD patients, flow rate should be set fast to maximize expiration time.
- Flow pattern: Rate of change of a flow rate.
- Fraction of inspired oxygen (FiO_2): The percentage of O_2 in the air delivered by ventilator.

In short, respiratory rate and tidal volume setting can contribute to reducing $PaCO_2$ whereas PEPP and FiO_2 settings can contribute to increasing O_2 level.

(Chartburn 2007)

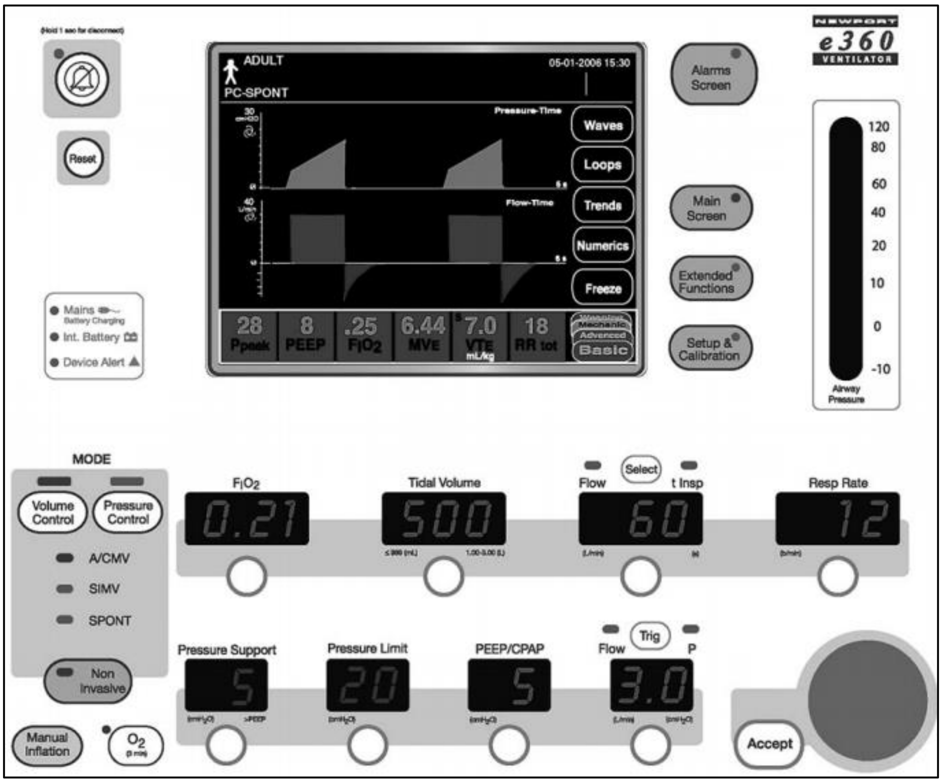


Figure 37. Newport e360 ventilator settings (Chartburn 2007)

c. Ventilator modes

Ventilators have different ventilator control modes, including volume modes and pressure modes, based on the respiratory cycle types suitable for the patient. Basically, ventilator mode is known as a set of operating characteristics that defines how the ventilator works.

Volume modes: The volume and flow are preset, pressure changes accordingly to lung compliance.

- Assist/Control mode (A/C)
- Synchronized intermittent mandatory ventilation mode (SIMV)

Pressure modes: The inspiratory pressure is preset, volume and flow change accordingly to lung compliance.

- Pressure support ventilation mode (PSV)
- Pressure-controlled ventilation mode (PCV)
- Airway pressure release ventilation mode (APRV)
- Volume-guaranteed pressure options mode (VGPO)
- Continuous positive airway pressure mode (CPAP)
- Noninvasive bilateral positive-pressure ventilation mode (BiPAP)

(Morton & Fontaine 2014, 594-601)

d. Ventilator's data reading

Figure x below illustrates how a ventilator screen looks like and where to recognize respiratory data on the screen.

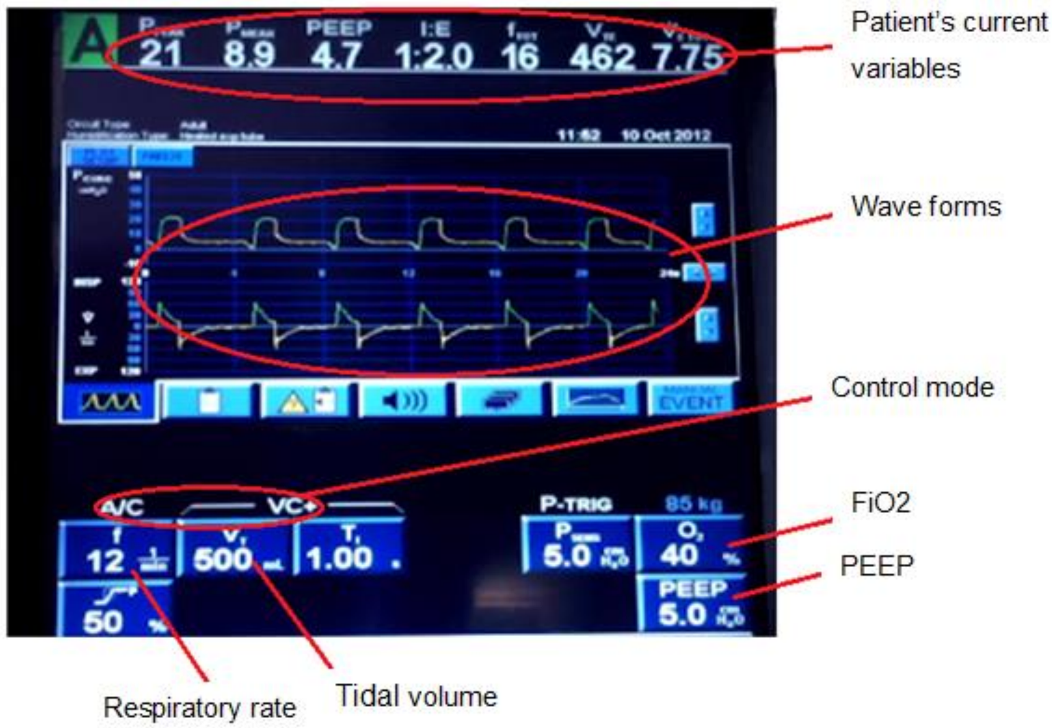


Figure 38. Ventilator data readings (DIMIU 2013)

6 DISCUSSION AND RESULT ASSESSMENT

The thesis´s aim and research questions were designated to provide a wide and unlimited scope for research possiblitiy. During the researching process, the thesis is objectively approached both from the perspectives of the researchers as well as the nurses. Being deeply motivated by the intensive care monitoring and nursing specialty, the authors have found this topic tremendously inspiring. In addition to evidence-based practices gardered during pratical trainings, nursing knowledge from different courses at school lays a good foundation for the final completion of this research.

The thesis´s aim has been well achieved. Through the background theory and findings of the thesis, the readers are practically provided with primary understanding of critical nursing care as well as cardiovascular and respiratory monitoring. With a variety of tables, figures, charts, pictures, definition, explaination, the thesis work has formed a concise, compact visualizing information package for nursing students as well as healthcare workers of the same interests.

Critical care monitoring was, is, and still going to be a complicated challenging aspect of nursing care. Hence, basic understanding of the topic is necessary which enhances motivation for further deeper researches and makes room for clinical practices improvements.

During the thesis process, cardiovascular and respiratory’s anatomy and physiology have been discussed in depth. By evidence-based method, the authors have described the main monitoring indicators in cardiovascular and respiratory monitoring in ICU settings. In contrast to the planning stage, the authors ended up limiting the thesis to the main basic devices and indicators in the finding stage due to the limited scope of a bachelor thesis.

This thesis takes roots from the author’s own interests and study motivations. Contrast with many other academic complicated available references of the same topic, this thesis is purposely performed in the most compact and understandable way, from which fresh nursing students can fully benefit and utilize.

6.1 Thesis ethical and reliability

In this thesis, ethical fundamentals are taken into consideration. The thesis questions were raised as the prime direction for the whole research construction. The topic took its birth from the authors' personal target of further learning and working in critical care specialties, and the self-realization of their lack of fundamental knowledge and practical experiences in ICUs practices. Knowledge foundation of cardiovascular and respiratory physiology and monitoring are inevitably necessary for students and nurses practicing in ICUs. (Eriksson et al. 2015, 63). From the personal perspective of the authors, cardiovascular and respiratory monitoring knowledge provided during nursing program is unfortunately not thoroughly and deeply enough to ensure working capabilities. All the new graduate nurses or nursing students going to intensive care units require further orientation and training (Woods et al. 2015, 359 – 368). As the result, the thesis topic is necessary and current topic which doesnot benefit the authors alone, but can be of great help to other students. The thesis methodology is literature review, in which information is gardered from various academic reliable sources. The thesis did not address any particular individuals or certain groups of patients. The references were cited carefully in detailed when using others authors' paperworks. In general, the thesis aims at gathering, analyzing and presenting the available information in the most beneficial way to answer the thesis's listed questions.

This research has been done by two authors in order to ensure the reliability of the literature review. The main methodology of this thesis is narrative systematic literature review, which means that the writers initially search for data, subsequently select the most benefinial and reliable, and finally handle them critically (Haddaway et al. 2015, 1596 - 1605). In addition to that, the methodology has been negotiated with teachers, audiences and opponents in the planning seminars. Both negatives and positives feedbacks were taken into consideration in order to increase the thesis reliability.

Research reliability is formed by designing logical stucture, handling findings as well as demonstrating terminologies clearly (Hrynchak et al. 2014, 870 - 883). Through the thesis process, the author's language proficiency has been increased dramatically. On the other hand, handling the information in Finnish, Vietnamese and English in order to ensure the comprehensive of literatures, the authors have come up with certain language difficulties.

In summary, the literatures used in this thesis include: 36 articles, 4 clinical text books (both Finnish and English), and a lot of information from Duodecim and Oppiportti page. The authors aim at presenting a multi-perspective and clear answer to the thesis questions, therefore, a lot of tables, figures and pictures have been utilized to visually demonstrate the work.

6.2 Thesis relevancy

The thesis topic and its appicability were sketched out carefully in the early stage of the thesis implementation. On the ground of this literature review, the authors have gathered most importants aspects of critical nursing care in ICU settings, which might be benefited dramatically during practical trainings or workplaces. Research methodology has benefited dramatically the authors in linguistic terms. At the same time, the authors have familiarized themselves to the acute monitoring terminologies, devices and processes. This thesis will benefit not only nursing students but also healthcare workers struggling with English terminologies and provide the most important concepts about cirtical nursing care, cardiovascular monitoring and respiratory monitoring.

6.3 Thesis limitations

The thesis topic is wide, challenging and complicated. Thus, choosing the most relevant aspects to present in this thesis is a real challenge. Moreover, the authors have encountered difficulties due to different perspectives of different authors concerning the same topics. Language limit can be a real barrier for information research in Finnish, making the authors' initial desire to learn more about Finnish critical care practices unfulfilled. As the result, the authors have concentrated on mostly English reliable references, leaving the Finnish sources at a small portion.

Another limitation of this thesis concerns the thesis scale. At the bachelor thesis level, the authors did not concentrate too much to the clinical understanding as well as mechanism of monitoring in the cirtical care settings. Hence, the findings were handled as the introduction knowledge to nursing students and healthcare workers only. This will make rooms for further researches of narrower scale and deeper approaches.

After finishing the thesis, it is realized that the findings were not based only on the clinical information database but also from other sources such as textbooks and national database for heathcare workers (Duodecim).

6.4 Career development

Yarbrough et al. (2016) have proved that competent critical care nurses are required to have a multidisciplinary knowledge based abilities. Cardiovascular and respiratory monitoring are among the most important skills in critical care nursing competences. During the thesis process, the authors take the most benefits from familiarizing themselves to this field and gaining a strong basic background for their future career development. Intensive nursing care is a challenging and demanding not only physically but also mentally. Understanding of monitoring devices is of great crucial as modern technical devices are nowadays actively involved in ICUs monitoring routine.

Mostly ICUs patients are in critical conditions and changes in their health status are fast and unexpectedly. Therefore, nurses are to react timely and decisely. That requires nurses' continuous self-developing in their skills and knowledge. The need of further career development is not beneficial for nurses themselves alone but is also part of nursing ethical aspects to better ensure the patient's safety.

The authors have chosen systematic literature review as thesis methodology, which is also an aspect of career development. Through the thesis process, the language proficiency of the authors has been improved significantly both in English and Finnish. The authors also know how to search for reliable sources of information related to the topic. In addition, the authors have learned to plan the research process and gaining a multi-perspective review of the literatures. During the thesis process, the authors find themselves to be highly responsible for the information presented, and motivated to learn more about topic after all. This contributes to personal career orientation and further development.

7 CONCLUSION AND RECOMMENDATION

In summary, the thesis has gone through the most important aspects of critical nursing care, cardiovascular monitoring and respiratoring monitoring. By using the systematic literature review methodology, the authors have reviewed multiperspective literatures related to the topic and given out the most important results of the thesis making process. The primary goal of the research is to support authors in future career development and education, however, healthcare workers as well as nursing students also find it benefit in clinical trainings and working places.

Due to the scope of the thesis and certain limitations which have been discussed in the thesis limitation part, the authors highly recommend further researches concerning the topic, specifically in respiratory monitoring and in cardiovascular monitoring. The interpretation of different ECG waves and respiratory mechanism has been introduced in this thesis at the basic level, which requires more detailed researches. Nursing interventions concerning cardiovascular and respiratory distresses are not fully mentioned. In addition, due to lacking of English literature about Finnish intensive care unit practices, the authors highly recommend Finnish researchers to carry out more English literatures to give an overall picture to international readers about Finnish practices.

REFERENCES

Public references

Abbasian A, Feiz Disfani H, Afzalimoghaddam M, Talebian MT, Masoumi B, Nasr-Esfahani M. 2015. Measurement of Central Venous Pressure Using Ultrasound in Emergency Department.

Aarno Kari & Petteri Mussalo. 2012. Tehohoidon kehitys Suomessa. Tehohoito 1, P. 318 - 320.

Abi-Saleh B, Omar B. 2010. Einthoven's triangle transparency: a practical method to explain limb lead configuration following single lead misplacements. 11(1): P. 33-38.

American Society of Anesthesiologists. 2009. Task Force on Sedation and Analgesia by Non-Anesthesiologists, Practice guidelines for sedation and analgesia by non-anesthesiologists. Anesthesiology: P. 1004 - 1017.

Antonini M, Meloncelli S, Dantimi C, Tosti S, Ciotti L, Gasparetto A. 2001. The PiCCO system with brachial-axillary artery access in hemodynamic monitoring during surgery of abdominal aortic aneurysm. Minerva Anestesiol, 67(6): P. 447-456.

Atlas of Human Anatomy. 2008. Anatomical Chart Company. 2008. P. 149.

Baura Gail D. 2012. Medical Device Technology. Mechanical Ventilators. Chapter 10. P. 217 – 236.

Becker Daniel E., Andrew B, Casabianca. P. 2009. Respiratory monitoring: Physiological and technical considerations.

Beest van PA, Hofstra JJ, Schultz MJ, Boerma EC, Spronk PE, Kuiper MA. 2008. The incidence of low venous oxygen saturation on admission to the intensive care unit: a multi-center observational study in The Netherlands. Retrieved in February 2016.

Beile Penny. 2006. On “Literature Reviews of, and for, Educational Research”: A Response to the Critique by Joseph Maxwell. Educational Researcher, December 2006; vol. 35, 9: P. 32-35.

Bigatello L.M., George. 2012. Hemodynamic monitoring. Minerva Anestesol first publication 2002. From the Department of Anesthesia and Critical Care, Massachusetts General Hospital Harvard Medical School, Boston, Massachusetts. 68: P. 219 – 225.

Blake Denise F., Elizabeth M. Shih, Paul Mateos, Lawrence H. Brown. 2014. The efficacy of oxygen wafting using different delivery devices, flow rates and device positioning. Australasian Emergency Nursing Journal, Volume 17, Issue 3, P. 119-125.

Blomster M, Mäkelä M, Ritmala- Castren M, Säämänen J, Varjus S-L. 2001. Tehohoitotyö. Retrieved in 2016 February.

Boote David N. 2005. Scholars Before Researchers: On the Centrality of the Dissertation Literature Review in Research Preparation. Educational Researcher, August 2005; vol. 34, 6: P. 3-15.

Brochard M. 2012. Critical Care Nursing, 16: P. 219

Chang Zong-xia, Yang Gui-Hua, Yuan Wei. 2014. Competency-based management effects on satisfaction of nurses and patients. International Journal of Nursing Sciences. P. 121 – 125.

Chen KP, Cavender S, Lee J, Feng M, Mark RG, Celi LA, Mukamal KJ, Danziger J. 2016. Peripheral Edema, Central Venous Pressure, and Risk of AKI in Critical Illness.

Coombs Maureen, Chaboyer Wendy, Lou Sole Mary. 2007. Advanced nursing roles in Critical Care – A natural or forced evolution? Journal of Professional Nursing. P. 83 – 90.

Crossley, Boyle, Vitense, Chang & Mead. 2011. The CONNECT Trial. J Am Coll Cardiol. P. 1181 -1189.

Darovic G. 2012. Hemodynamic Monitoring: Invasive and Noninvasive Clinical Application, 6th ed. Philadelphia: WB Saunders. 3rd ed 2002.

Dash. P.K. 2012. Indian J. Anaesth. Electrocardiogram Monitoring; 46 (4): P. 251-260

DIMIU. 2013. Department of Internal Medicine Indiana University. Critical care survival guide. Online lecture for your ICU rotation. Retreived in February 2016.

Drew BJ, Califf RM, Funk M, et al. 2014. Practice standards for electrocardiographic monitoring in hospital settings: An American Heart Association scientific statement from the Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young. Circulation 110: P. 2721 – 2746

Edwards Lifesciences. 2015. Understanding continuous mixed venous oxygen saturation (SvO2) monitoring with the Swan-Ganz oximetry TD system. 2nd edition in 2002.

Fahy Bonnie, Suzanne Lareau, Marianna Sockrider. Journal of American thoracic society. 2013. Patient information series: Pulse oximetry.

Fry M. 2011. Literature review of the impact of nurse practitioners in critical care services. Nursing in Critical Care, P. 58 – 66.

Gazarian PK, Carrier N, Cohen R, Schram H, Shiromani S. 2015 Jan. A description of nurses' decision-making in managing electrocardiographic monitor alarms. 24(1-2): P. 151-159.

Goldhill DR, White SA, Sumner A. 1999. Physiological values and procedures in the 24 h before ICU admission from the ward. Anaesthesia; 54(6): P. 529–534.

Guyton AC, Hall JE. 2006. Textbook of Medical Physiology. 11th ed. Philadelphia: Elsevier Inc: P. 471 – 522

Gormersal Charles. 2016. WHO. World Health Organization. Critical Care training. Invasive arterial pressure monitoring.

Goodarzi H, Javadzadeh H, Hassanpour K. 2015. Assessing the Physical Environment of Emergency Departments.

Graneheim UH, Lundman B. 2004 Feb. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. 24(2): P. 105-112.

Grasso Francesco, Doreen Engelberts, Emma Helm, Helena Frndova, Steven Jarvis, Omid Talakoub, Colin McKerlie, Paul Babyn, Martin Post, and Brian P. Kavanagh. 2008. Negative pressure ventilation, presented in American Journal of Respiratory and Critical Care Medicine, P. 412-418.

Haddaway N. R., Woodcock P., Macura B., Collins A. 2015.Making literature reviews more reliable through application of lessons from systematic reviews. P. 1596-1605

Hagberg Carin A., Felice E. Agro, Tim M. Cook, Allan P. Reed. 2007. Benumof's Airway Management (Second Edition). Chapter 22 - New Generation Supraglottic Ventilatory Devices. P. 502-531

Hall John E. 2011. Guyton and Hall Textbook of Medical Physiology. Twelflth edition. Chapter 39, P. 485-492

Hardcastle Timothy C., Michael Faurie, David J.J. Muckart. 2015. Endotracheal tube cuff pressures and tube position in critically injured patients on arrival at a referral centre: Avoidable harm? African Journal of Emergency Medicine. Retrieved in February 2016.

Headley JM. 2013. Arterial Pressure-Based Technologies: A New Trend in Cardiac Output Monitoring. First publication 2006. Crit Care Nurs Clin N AM 18: P. 179 – 187

Hravnak M, Edwards L, Clontz A, Valenta C, Devita MA, Pinsky MR. 2008. Defining the incidence of cardiorespiratory instability in patients in step-down units using an electronic integrated monitoring system. 168(12): P. 1300-1308.

Hrynchak Patricia, Glover Takahashi Susan, Nayer Marla. 2014. Key-feature questions for assessment of clinical reasoning: a literature review. Medical Education. P. 870-883.

Hsieh Hsiu-Fang & Shannon Sarah E. 2005. Three Approaches to Qualitative Content Analysis. Qualitative Health Research. Vol. 15 Issue 9, P. 1277-1288.

Huff J. 2012. EKG Workout: Exercises in Arrhythmia Interpretation, 7th ed, Philadelphia: Lippincott.

Hughes Martin, Jane Kyle, Abigail Short. 2013. Ventilatory support in the intensive care unit. Anaesthesia & Intensive Care Medicine, Volume 14, Issue 10. P. 466-471

Jacq G, Gritti K, Carré C, Fleury N, Lang A, Courau-Courtois J, Bedos JP, Legriel S. 2015. Modalities of Invasive Arterial Pressure Monitoring in Critically Ill Patients: A Prospective Observational Study.

John B. West MD, PhD. 2015. UC San Diego School of Medicine. Lectures in Respiratory physiology.

Johnson K., S. Bayliss, J. Masters, K. Rolls. 2014. Open versus closed suctioning of artificial airways in critically ill adult patients: An evidence review. Australian Critical Care, Volume 27, Issue 1, P. 58.

Johnson KL. 2009. Diagonostic measures to evaluate oxygenation in critically ill adults.

Jones M, Olorvida E, Monger K, Yarborough V, Bennetts H, Harris D, Keith C, Boggs L, Firrincieli B, Ingram L, Richardson P, Locklear D, Sigmon S, Lewis J, Murphy J. 2015. How Well Do Inexpensive, Portable Pulse Oximeter Values Agree with Arterial Oxygenation Saturation in Acutely Ill Patients? 24(6): P. 391-396.

Junttila E. 2014. Hengitylsen valvonta. Anesthesiologian and tehohoidon perusteet.

Kleinpell R.M., Ely E.W. and Grabenkort R. 2008. Nurse practitioners and physician assistants in the intensive care unit: an evidence physician assistants in the intensive care unit: an evidence – based review.

Kluwer Wolters. 2013. Critical Care Challenges: Disorders, Treatments, and Procedures.

Kosovskaya Daria. 2015. Hengityksen fysiologia, valvonta ja hengityslaitehoito aikuisten tehohoitotyössä. P. 21.

Krahn, Klein, Yee, Hoch, Skanes. 2003. Cost implications of testing strategy in patients with syncope. J Am Coll Cardiol.

Kreso A, Barakovic F, Medjedovic S, Halilbasic A, Klepic M. 2015. Electrocardiographic and Echocardiographic Imaging of the Heart of Athletes and Patients with Hypertension. 69(5): P. 319-322.

Lakanmaa Riitta – Liisa. 2012. Competence in intensive and critical care nursing – development of a basic assessment scale for graduating nursing students. University of Turku.

Lakanmaa Riitta - Liisa, Suominen Tarja, Ritmala-Castrén Marita, Vahlberg Tero, and Leino-Kilpi Helena. 2015. Basic Competence of Intensive Care Unit Nurses: Cross-Sectional Survey Study. Received 28 December 2014; Accepted 23 April 2015.

Larkin Brenda G. & Zimmanck Robert J. 2015. Interpreting Arterial Blood Gases Successfully. AORN Journal, Volume 102, Issue 4, P. 343-357

Leibowitz AB, Oropello JM. 2007. The pulmonary artery catheter in anesthesia practice in 2007: an historical overview with emphasis on the past 6 years. Semin Cardiothorac Vasc Anesth, 11(3): P. 162-176

Leino-Kilpi H, Välimäki M. 2004. Etiikka hoitotyössä. Retrieved in 2016 February.

Magder, S. 2007. Invasive Intravascular Hemodynamic Monitoring: Technical Issues. Critical Care Clinics. 23(3).

Martin J. Tobin. 1988. Respiratory Monitoring in the Intensive Care Unit, American Review of Respiratory Disease, Vol. 138, No. 6, P. 1625-1642.

Masclans J.R., P. Pérez-Terán, O. Roca. 2015. The role of high-flow oxygen therapy in acute respiratory failure. Medicina Intensiva (English Edition), Volume 39, Issue 8, P. 505-515.

McGain F, Cretikos MA, Jones D, Van Dyk S, Buist MD, Opdam H, et al. 2008. Documentation of clinical review and vital signs after major surgery. Med J Aust; 189(7): P. 380 – 383.

Meriläinen Merja. 2012. Intensive care unit patients' environment. Psychological quality of life and recovery. University of Oulu Graduate School.

Minvielle E, Aegerter P, Dervaux B, Boumendil A, Retbi A, Jars-Guincestre MC, Guidet B. 2008. Assessing organizational performance in intensive care units: a French experience.

Morton P.G, Fontaine D.K. 2014. Critical care nursing. A holistic approach. International edition. 11th edition.

Mulryan Chris. 2014. Acute illness management. SAGE publication. First published 2011. P. 168.

Mulryan Chris. 2014. Acute illness management. SAGE publication. First published 2011. P. 125.

Müller S, Velik-Salchner C, Edlinger M, Bonaros N, Heinz A, Feuchtner G, Bartel T. 2015. J Am Soc Echocardiogr. 2016. Intracardiac Doppler Echocardiography for Monitoring of Pulmonary Artery Pressures in High-Risk Patients Undergoing Transcatheter Aortic Valve Replacement. 29(1): P. 83-91

Potestio, Melissa L., Boyd, Jamie M., Bagshaw, Sean M., Heyland, Daren, Oxland, Peter; Doig, Christopher J., Zygun, Dave, Stelfox, Henry T. 2015. Engaging the Public to Identify Opportunities to Improve Critical Care: A Qualitative Analysis of an Open Community Forum. Vol. 10 Issue 11, P. 1-11.

Preedy E. Callard & Prokopovich P. 2013. Anatomy and pathophysiology of the respiratory system. Inhaler devices. P. 3 – 12

Pryor Jennifer A., Ammani Prasad S. Edited by Jennifer A. Pryor, S. Ammani Prasad. 2008. Physiotherapy for respiratory and cardiac problems: adults and paediatrics. Chapter 1. Assessment and investigation of patients' problems

Pyykkö A. 2014. Tehohoitotyön mallin kehittäminen ja arviointi.

Ramnarayan P, Thiru K, Parslow RC, Harrison DA, Draper ES, Rowan KM. 2010. Effect of specialist retrieval teams on outcomes in children admitted to paediatric intensive care units in England and Wales: a retrospective cohort study.

Reinikainen Matti. 2012. Hospital Mortality of Intensive Care Patients in Finland. Insights into Prognostic Factors and Measuring Outcomes. Department of Anaesthesiology and Intensive Care, Institute of Clinical Medicine.

Reinikainen M, Uusaro A, Niskanen M, Ruokonen E. 2007. Intensive care of the elderly in Finland. 51(5): P. 522-529.

Rosenberg P., Ruokonen E., Alahuhta S., Lindgren L., Olkkola K. & Ruokonen E. (toim.). 2014. Anestesiologia ja tehohoito. Duodecim, P. 14-16.

Roulston Kathryn. 2016. Issues involved in methodological analyses of research interviews. Qualitative Research Journal. Vol. 16 Iss: 1, P. 68 – 79

Santiago-Delefosse M., A. Gavin, C. Bruchez, P. Roux, S.L. Stephen. 2016. Quality of qualitative research in the health sciences: Analysis of the common criteria present in 58 assessment guidelines by expert users. Volume 148, P. 142-151

Shaw Michelle & Chishti Ahmed. 2016. Advanced cardiovascular monitoring. Surgery (Oxford)

Sivaraman Jayaraman, Uma Gandhi, Venkatesan Sangareddi, Umapathy Mangalanathan, Dhandapani Vella Elumalai. 2015. Normal limits of ECG measurements related to atrial activity using a modified limb lead system. Journal of Cardiology 15(1): P. 2-6.

Sondergaard S, Parkin G, Aneman A. 2016. Central venous pressure: soon an outcome-associated matter.

Spoletini Giulia, Mona Alotaibi, Francesco Blasi, Nicholas S. Hill. 2015. Heated Humidified High-Flow Nasal Oxygen in Adults. Volume 148, Issue 1, P. 253-261.

Stover John F, Reto Stocker, Renato Lenherr, Thomas A Neff, Silvia R Cottini, Bernhard Zoller and Markus Béchir. 2009. Noninvasive cardiac output and blood pressure monitoring cannot replace an invasive monitoring system in critically ill patients.

Sungyoup Hong. 2009. Performance study of the wearable one-lead wireless electrocardiographic monitoring system. Telemedicine and e-Health. 15 (2), P. 166-175

Tanzilli G, Truscelli G, Barillà F, Cocco N, Pannitteri G, Tanzilli A, Al Kindy S, Mangieri E, Gaudio C. 2015. Evaluation of hand circulation with CardioWaves photoplethysmograph device during Allen test in healthy volunteers. 19(16): P. 3006-3011

Truwit Jonathon D. & Scott K. Epstein. 2011. Practical guide to mechanical ventilation. P. 3-31

Truwit Jonathon D. & Scott K. Epstein. 2011. Practical guide to mechanical ventilation. P. 95-103

Tuomi, J. & Sarajärvi, A. 2009. Laadullinen tutkimus ja sisällönanalyysi. Painos 5. Helsinki: Tammi. P. 113 – 117

Varjavand Nielufar, Jonathan M. Kayne, Shaojie Wang, Frank P. Primiano. 2000. The interactive oxyhemoglobin dissociation curve.

Varpula Tero. 2011. Duodecim. Terveysfoorumi. Tehohoidon valinnat. HYKS Jorvin Sairaala. Helsingin ja Uudenmaan sairaanhoitopiiri.

Ward Jeremy P.T., Jane Ward, Richard M. Leach. 2010. The respiratory system at a glance. Third edition. P. 54-57.

Whitemore Robin and Kathleen Knafl. 2 Nov 2005. The integrative review: updated methodology. Retrieved in 2016 February.

Wildsmith JA. 2003 December. Regional anesthesia. Anaesthesia. 58(12): P. 1200-1203.

Williams Lippincott & Wilkins. 2003. Guidelines on critical care services and personnel: Recommendations based on a system of categorization of three levels of care. Retrieved in February 2016.

Winslow Robert M. 2007. The role of hemoglobin oxygen affinity in oxygen transport at high altitude. P. 121 – 127. Retrieved in February 2016.

Woods C, West C, Mills J, Park T, Southern J, Usher K. 2015. Undergraduate student nurses' self-reported preparedness for practice. P. 359-368.

Yarbrough S, Martin P, Alfred D, McNeill C. 2016. Professional values, job satisfaction, career development, and intent to stay.

Yuan George, Nicole A. Drost, R. Andrew McIvor. 2013. Respiratory rate and breathing pattern. Clinical review. P. 23

Zorzi A, Peruzza F, Stella F, Del Monte A, Migliore F, Gasparetto N, Badano L, Iliceto S, Corrado D. 2016. Life-threatening ventricular tachyarrhythmias in the cardiology department: Implications for appropriate prescription of telemetry monitoring. 101: P. 6-11.

Electronic references

AIHW. 2012. Australian Government. Australian Institute of Health and Welfare. Intensive care unit. Retrieved in 2016 February. Available at http://meteor.aihw.gov.au/content/index.phtml/itemId/327234

ATS. 2015. American thoracic society. Patient information series: Chest tube thoracostomy. Available at: https://www.thoracic.org/patients/patient-resources/resources/chest-tube-thoracostomy.pdf

Camporota Luigi, Francesca Rubulotta. 2012. Respiratory assessment and monitoring: Skills and techniques. Retrieved in 2016 February. Available at: http://pact.esicm.org/media/Respiratory%20Assessment%20and%20Monitoring%2028%20Feb%202012%20final.pdf

Chartburn Robert L. 2007. Classification of Ventilator Modes: Update and Proposal for Implementation. Retrieved in February 2016. Available at: http://rc.rcjournal.com/content/52/3/301.full.pdf

Cssolutions. 2016. An example of a pulmonary artery pressure monitoring system. Retrieved in February 2016. Available at: http://www.cssolutions.biz/hemo1s.html

Department of Health (2000) Comprehensive critical care, a review of adult critical care services. Available at: www.doh.gov.uk/pdfs/criticalcare.pdf

DHE.2003. Department of Health for England. Retrieved in 2016 February. Available at: https://www.gov.uk/government/organisations/department-of-health

EMP. 2015. Emergency medical products. Available at website: http://www.buyemp.com/

Eriksson E., Korhonen T., Merasto M. ja Moisio E. 2015. Sairaanhoitajan ammatillinen osaaminen. Sairaanhoitajakoulutuksen tulevaisuus - hanke.

Ammattikorkeakoulujen terveysalan verkosto ja Suomen sairaanhoitajaliitto ry. Retrieved in February 2016. Available at: https://www.tehy.fi/@Bin/31009045/loppuraportti-sairaanhoitajan-ammatillinenosaaminen.pdf

Farabee. M. J. 2016. The respiratory system. The Human respiratory system. Retrieved in February 2016. Avaiable at: http://www2.estrellamountain.edu/faculty/farabee/biobk/BioBookRESPSYS.html

Galley Julia, O'Riordan Bernadette. 2003. Guidance for nurse staffing in critical care. Retrieved in 2016 February. Available at http://www.rcn.org.uk/__data/assets/pdf_file/0008/78560/001976.pdf

HUS. 2016. Intensive care. Retrieved in 2016 February. Available at http://www.hus.fi/en/medical-care/medical-services/intensive_care/Pages/default.aspx

ICCMU. 2009. Intensive Care Co- Ordination and Monitoring Unit. ICU definition. Retrieved in February 2016. Available at: http://www.aci.health.nsw.gov.au/networks/intensive-care/community/icu_definition#a1

Imonus. 2016. Imonusolf. Gallery for – Diagram of Alveoli and Capillari. Retrieved in February 2016. Available at: www9.imonusolf.tk

JBTS. 2015. Journal of the British Thoracic Society. BTS guidelines for home oxygen use in adults. Available at https://www.brit-thoracic.org.uk/document-library/clinical-information/oxygen/home-oxygen-guideline-(adults)/bts-guidelines-for-home-oxygen-use-in-adults/

Kidneyfund. 2016. Retrieved in February 2016. Available at: http://www.kidneyfund.org/kidney-disease/esrd-treatment/vascular-access/

LITFL 2016. Life in the fast lane. Lead positioning. Retrieved in February 2016. Available at http://lifeinthefastlane.com/education/lead-positioning/

Lund Vesa E. 2011. Suomen lääkärilehti 13/2011 vsk 66. Retrieved in 2016 February. Availble at http://www.laakarilehti.fi/files/nostot/2011/nosto13_2.pdf

McPhee SJ. & Ganong WF. 2016. Pathophysiology of Disease. An Introduction to Clinical Medicin. 5th Edition. Available at: http://accessmedicine.com

Miller-Keane. 2016. Encyclopedia and Dictionary of Medicine, Nursing, and Allied Health, Seventh Edition. S.v. "hemodynamic monitoring." Retrieved February 11 2016 from http://medical-dictionary.thefreedictionary.com/hemodynamic+monitoring

MNH. 2015. Mount Nittany Health. Chest tubes. Available at: http://www.mountnittany.org/articles/healthsheets/12360

MSAH. 2013. Ministry of Social Affairs and Health. Health care in Finland. Retrieved in February 2016. Available at: https://www.julkari.fi/bitstream/handle/10024/110284/URN_ISBN_978-952-00-3395-8.pdf?sequence=1

NMM. 2015. Nucleus medical media. Presented by University of Virginia: Intubation and mechanical ventilation. Available at http://uvahealth.com/services/surgery/intubation-and-mechanical-ventilation

Polymedicure. 2016. Retrieved in February 2016. Available at: http://www.polymedicure.com/?wpccategories=central-venous-catheters

QRS. 2015. Queensland Ambulance Service clinical practice manual. Airway management/ Oropharyngeal airway insertion. Available at: https://ambulance.qld.gov.au/%5Cdocs%5Cclinical%5Ccpp%5CCPP_Oropharyngeal%20airway%20insertion.pdf

Siirilä Niina. 2008. Tehohoitotyön laatu. P. 2. Retrieved in February 2016. Availale at https://tampub.uta.fi/bitstream/handle/10024/79643/gradu03083.pdf

Singer Mervyn, Webb Andrew R. 2009. Oxford handbook of critical care. Third edition. Chapter 1, P. 4. Retrieved in 2016 February. Available at http://site.ebrary.com.aineistot.lamk.fi/lib/lamk/reader.action?docID=10581443

STHY. 2015. Suomen tehohoitoyhdistys. Lists of ICUs in Finland. Retrieved in February 2016. Available at http://www.sthy.fi/teho-osastot

APPENDIX

List of Finnish critical care units (STHY 2015)

Hospitals	Head doctor	Head nurse	Capa -city	Visiting address
Etelä-Karjalan keskussairaala, Teho-osasto	Seppo Hovilehto	Merja Lahtinen	6	Valto Käkelänkatu 1 Lappeenranta53130
HYKS Jorvin sairaala, Teoho-osasto	Tero Varpula	Riitta Donner	8	Turuntie 150 Espoo 02740
HYKS lasten ja nuorten sairaala vastasyntyneiden teho-osasto	Sture Andersson	Elisabeth Mäntysalo	11+5	Stenbäckinkatu 11 PL 281 HUS 00029
HYKS Lastenklinikka, Lasten teho-osasto K9	Paula Rautiainen	Merja Ahde	14	Stenbäckinkatu 11 HUS 00029
HYKS Meiladen sairaala sydänkirurginen teho-osasto 21	Raili Suojaranta-Ylinen	Laura Laitinen	14	Haartmaninkatu 4 PL 340 HUS 00029
HYKS Meilahden sairaala Teho-osasto 20	Marja Hynninen marja.hynninen@hus.fi	Anneli Övermark anneli.overmark @hus.fi	16	Haartmaninkatu 4 2. krs, PL 340 HUS 00029
HYKS Meilahden sairaala Valvontaosasto 22	Tom Bäcklund tom.backlund @hus.fi	Maritta Olsbo-Nurminen maritta.olsbo-nurminen@hus.fi	10	Haartmaninkatu 4 HUS 00029
HYKS Peijaksen sairaala TVO / CCU	Juhani Rossinen	Ulla Kohvakka	6	Sairaalakatu 1 Vantaa 01400
HYKS Töölön sairaala Neurokirurginen	Jari Siironen	Petra Ylikukkonen	10 + 6	Topeliuksenkatu 5 HUS 00029

teho- ja valvontaosasto		petra.ylikukkonen@hus.fi		
HYKS Töölön sairaala Palovammaosasto	Jyrki Vuola	Markku Laitila	3 + 3	Topeliuksenkatu 5 HUS 00029
HYKS Töölön sairaala, teho-osasto	Janne Reitala	Satu Poikajärvi satu.poikajarvi@hus.fi	10	Topeliuksenkatu 5 2. krs PL 266 HUS 00029
Hyvinkään sairaala, Tehostetun valvonnan yksikkö	Riitta Palojoki	Kirsi Mikkonen	8	Sairaalankatu 1 Hyvinkää 05800
Intensivvårds- och dialysavdelning, Ålands hälso- och sjukvård	Mats-Ola Mattsson mats-ola.mattsson@ahs.ax	Sirpa Mankinen sirpa.mankinen@ahs.ax	4 tehovalvontapaikkaa	Doctorsvägen 1 Mariehamn 22100
Kainuun keskussairaala, teho-osasto	Sami Mäenpää	Tiina Kähkönen	6	Sotkamontie 14 Kajaani 87100
Kanta-Hämeen keskussairaala, Tehostetun hoidon osasto/Sydänvalvonta	Ville Salanto heinäkuuhun asti/Ari Alaspää	Helena Illikainen		Ahvenisto Hämeenlinna 13530
Keski-Pohjanmaan keskussairaala, Teho-osasto	Tadeusz Kaminski	Kaija Ojanperä	4 + 1	Mariankatu 16-20 Kokkola 67200
Keski-Suomen keskussairaala, Teho-osasto	Raili Laru-Sompa	Päivi Ridell	8 + 4	Keskussairaalantie 19 Jyväskylä 40620

Kymenlaakson keskussairaala, Sydänvalvonta	Jaana Yrjölä	Tiina Vierula		Kotkantie 41 Kotka 48210
Kymenlaakson keskussairaala, Teho-osasto	Seija Alila	Tiina Vierula	6	Kotkantie 41 Kotka 48120
KYS	Esko Ruokonen	Ulla Kesti	23	Kuopio 70211
Länsi-Pohjan keskussairaala, Teho-osasto	Simo Lavander	Ulla-Maija Kärki	5	Kauppakatu 25 Kemi 94100
Länsi-Uudenmaan sairala, tehovalvonta-osasto	Jukka Rinne jukka.rinne@hus.fi	Kari Mattila kari.mattila@hus.fi	4	Ormnäsintie 1 PL 1020 Tammisaari 10600
Lapin keskussairaala, Teho-osasto	Outi Kiviniemi	Aino Vallo	8	Ounasrinteentie 22 Rovaniemi 96400
Lohjan Sairaala, Tehovalvonta-osasto	Juha Valtonen	Liisa Marttila	6	Sairaalatie 8 Lohja 08200
Maarian sairaala, valvontaosasto M1	Sakari Mänttäri	Anne Surakka	10	Talvelantie 6 Helsinki 00700
Marian sairaala Valvontaosasto	Risto Pajari	Leena Puolakanaho		Lapinlahdenkatu 16 PL 580 HUS 00029
Mikkelin keskussairaala, Teho-osasto	Heikki Laine/Janne Kuusela	Anna-Liisa Hahl	5	Porrassalmenkatu 35-37 Mikkeli 50100
OYS Lasten teho os 64	Outi Peltoniemi outi.peltoniemi@ppshp.fi	Kristiina Piironen krpi@mbnet.fi	10	Oulu 90221
OYS Sisätautien Teho-osasto	Kirsi Majamaa-Voltti kirsi.majamaa-	Marko Knuutila marko.knuutila@ppshp.fi	8	Oulu 90221

	voltti@ppshp.fi			
OYS Teho 1	Tero Ala-Kokko	Minna Lahtinen	11 + 4	Oulu 90221
OYS Teho 2	Tero Ala-Kokko	Marjaana Haataja	11	Oulu 90221
Päijät-Hämeen keskussairaala, Teho-osasto	Pekka Loisa	Päivi Riutta	8	Keskussairaalankatu 7 Lahti 15850
Pohjois-Karjalan keskussairaala, Teho-osasto	Matti Reinikainen matti.reinikainen@pkssk.fi	Seija Virranta seija.virranta@pkssk.fi	8	Tikkamäentie 16 Joensuu 80210
Pohjois-Kymen sairaala, Tehostettu valvontaosasto	Miia Melkoniemi miia.melkoniemi@kouvola.fi	Jukka Tiitola jukka.tiitola@kouvola.fi	4+1	Sairaalamäki Kuusankoski 45750
Porvoon Sairaala Tehostettu valvonta	Marian Ahlskog-Karhu	Marika Innanen	4	Sairaalantie 1 Porvoo 06151
Satakunnan keskussairaala, Teho-osasto	Vesa Lund	Raija Säviaho	7 + 6	Sairaalantie 3 Pori 28500
Savonlinnan keskussairaala, Tehostettu valvontaosasto	Pekka Saastamoinen pekka.saastamoinen@isshp.fi	Eija Korhonen	5	Keskussairaalantie 6 Savonlinna 57170
Seinäjoen keskussairaala, Neuroteho/valvonta	Lauri Herrala	Liisa Ala-Hynnilä		
Seinäjoen keskussairaala, Teho-osasto	Kari Saarinen	Liisa Ala-Hynnilä	7 + 4	Hanneksenrinne Seinäjoki 60200

TAYS Sydänsairaala / Sydänteho-osasto	Kati Järvelä	Riitta Raunio riitta.raunio@sydansairaala.fi	7	Teiskontie 35 Tampere 33521
TAYS, Teho-osasto	Sari Karlsson Sari.Karlsson @pshp.fi	Liisa Karhe	16 + 8	Teiskontie 35 Tampere 33521
TYKS, Aikuisten teho-osasto	Mika Valtonen mika.valtonen @tyks.fi	Tapio Korhonen ja Pirjo Partanen tapio.j.korhonen @tyks.fi	24	Hämeentie 11 Turku 20521
TYKS, Kirurginen sairaala Valvontaosasto 951	Antti Liukas antti.liukas@tyks.fi	Kaija Tuononen kaija.tuononen @tyks.fi	6 + 2	Luolavuorentie 2 Turku 20700
TYKS, Lasten teho-osasto	Janne Kataja janne.kataja@tyks.fi	Riitta-Maija Hokkanen riitta-maija.hokkanen @tyks.fi	3 + 3	Kiinamyllynkatu 4-8 Turku 20521
Vaasan keskussairaala, Teho-osasto	Simo-Pekka Koivisto simo-pekka.koivisto @vshp.fi	Inger Lähdesmäki inger.lahdesmaki@vshp.fi	10	Hietalahdenkatu 2-4 Vaasa 65130