Home Exam
Biomedical Instrumentation
SSY 091

Qixun Qu

qixun@student.chalmers.se

15/12/2016

Qixun Qu [redacted]

1. Task One

1.1 Neonatal Resuscitation

A neonatal may suffer from breathing difficulty at the time of birth, in which case neonatal resuscitation should to be carried out to assistant baby to recover respiratory function. Procedures of neonatal resuscitation is shown as the block diagram in Figure 1.1. First of all, evaluate the physical condition of neonatal to determine whether resuscitation steps need to be applied. There are three questions, such as “Term gestation?” “Breathing or crying?” and “Good tone?”, to make judgement in a short time. If baby is in a good condition, he/she will be taken care of by routine steps. (Routine care consists of keeping baby warm, cleaning airway if necessary, drying the body and making evaluation.) If not, resuscitation steps should be implemented.

Step A. Stabilization In this step, keep baby warm and dry baby’s body. It is important that clean airway if necessary to make air path fully open. After which, if baby has a heart rate (HR) that is above 100 per minute with gentle breathing, he/she can be taken care of routine care. If baby breaths heavily, he/she should be transferred to a ward where monitoring and therapy can be provided timely if necessary.

Step B. Ventilation In the case that the HR of infant is lower than 100 per minute or infant is still not able to breathe normally with gasping or apnea, positive pressure ventilation (PPV) should be implemented to start effective respiratory with supplemental O_2. Applying Step A and beginning the ventilation should be finished in the first 60 seconds after birth. After the stimulation of PPV, if infant’s HR is above 100 per minute, he/she can be taken in postresuscitation care. If not, steps of PPV should be corrected.

Step C. Chest Compression When PPV cannot improve infant’s HR, chest compression with each breath should be applied to establish normal circulation of infant.

Step D. Medication If HR of infant remains lower than 60 per minute, drugs should be administrated to increase the level of HR. Epinephrine is useful for this case, but it is rarely in real situation that infant gets drugs while in the process of resuscitation.

Step E. Evaluation After each step being implemented, an accurate evaluation of infant’s condition should be done in time. Evaluation can tell the performance of each step, giving advice to promote the procedure. All description above and the idea of the figure are inspired by the reference [1].

Here, two kinds of ventilators will be introduced, they are self-inflating bag and T-piece resuscitator. The structure of self-inflating bag is shown in Figure 1.2. A typical self-inflating bag is called AMBU bag. Figure 1.3 shows a typical infant T-piece resuscitator designed by *Neopuff*^{TM}.

The body of self-inflating bag is made by the material that has the ability to expand itself when released after compression. Thus, it always remains inflated, and it is able to fill itself spontaneously by pulling O_2 or air into bag. The inlet valve is closed when bag is compressed, and opened when bag is released to let O_2 or air flow in. After connecting O_2 source and O_2 reservoir bag, it can be used for the purpose of infant resuscitation. The patient valve will be closed to prevent expiration air flowing back to the bag when patient exhales. However, one disadvantage of self-inflating bag is that there is no manometer to show the pressure of flowing-in O_2 or air. If the patient is an infant, high continuous positive airway pressure (CPAP) may hurt his/her lung [2]. Compared to self-inflating bag, T-piece

resuscitator has many advantages, because there are many gauges that show the state of pressure for continuous monitoring. It is able to deliver consistent peak inspiratory pressure (PIP) and positive end expiratory pressure (PEEP). Doctors can control the flowing-in O_2 by configuring setting, such as inspiratory time and maximum pressure [3]. In fact, there is another one ventilator called flow-inflating bag. It features a soft bag and has ability to provide sustained inflations with compressed O_2. A manometer also can show the state of pressure. But enough experience is required to handle this ventilator [3].

What's the meaning of PIP, PEEP and CPAP? How can these parameters influence the neonate? PIP is the highest pressure in lung during inspiration. CPAP is the pressure that can keep airway open throughout the breathing cycle. PEEP is the pressure in lung at the end of expiration. If these parameters are set in a proper range, the ventilator can treat infants who have trouble in breathing, and help them to develop their respiratory system [4]. On the contrary, improper parameters will damage the infant's tender organs, especially the lung. The other two parameters that can influence neonate are input O_2 concentration (FiO_2) and breathing rate per minute.

1.2 Respiratory System

In the process of inspiration, air gets through the nasal cavity, oral cavity, pharynx, larynx, trachea, and all levels bronchus in sequence. Eventually, the air in pulmonary alveoli is exchanged with the gas in capillaries. The gas is exhaled out body over the same route.

The mechanic model of respiratory system is shown in Figure 1.4 and Equations 1.1, 1.2 and 1.3. The model is divided into two parts which are airway resistance and pulmonary compliance. Airway resistance indicates the resistance of respiratory tract to the air that can be applied to calculate the air pressure in the respiratory tract.

The pressure difference P_R between the lung and outside of body can be regarded as a potential difference, R is the resistance of respiratory tract, and $\dot{V}$ is the volumetric airflow that can be seen as current. Thus, the model of respiratory tract can be derived by Ohm's Law as shown in Equation 1.1. Pulmonary compliance describes the ability of lung to expand, indicating the inner pressure of lung. The lung can be seen as a capacitor C, ΔV is the change of lung's volume that is the integration of $\dot{V}$. Thus, the voltage (pressure) inner lung can be computed as Equation 1.2. If it is balance between inside body and outside body, the pressure inner lung is equal to atmosphere pressure as shown in Equation 1.3. During the process of expiration, ΔV is becoming smaller so that pressure in lung is lower than atmosphere pressure. Air will be pressed in lung during inspiration, resulting in the increasing of ΔV as well as pressure in lung. Pulmonary gas is able to be exhaled since inner pressure is bigger than atmosphere pressure.

$$P_R = \dot{V}R \qquad (1.1) \qquad P_C = \Delta V/C \qquad (1.2) \qquad P_V = P_C + P_R \qquad (1.3)$$

Comparing with adults, neonates' is lung function is unique because of the differences in physical structure. The nasal passage of an infant is narrow, but the tongue is large, resulting in the high airway resistance. Therefore, infants is more likely to suffer from respiratory distress and nasal obstruction. The respiratory function is imperfection. The chest wall of neonate is more compliant and intercostal muscles is weaker than adult's. Also, the diaphragm of infant is flatter and smaller. So that neonate cannot handle the mechanic process of breath. Infant's alveoli is smaller than adult's, causing less surface of gas exchange. Infants have a greater tendency to develop pulmonary incompetence [5].

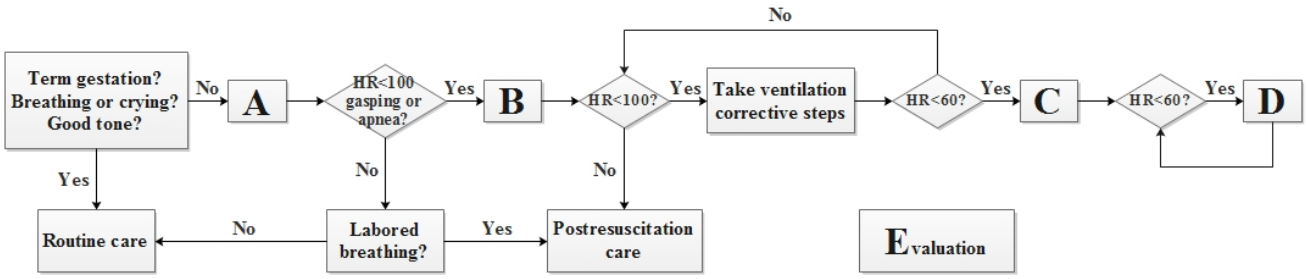

Figure 1.1 Procedures of Neonatal Resuscitation

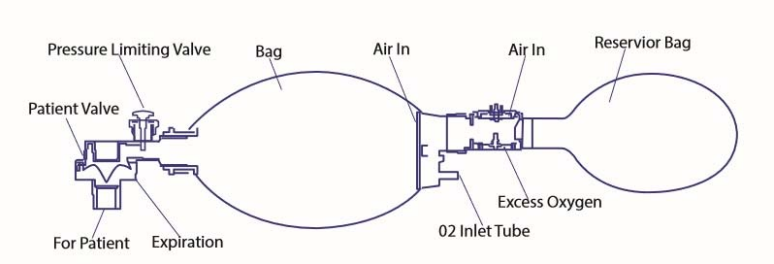

Figure 1.2 Self-inflating Bag [6]

Figure 1.3 T-piece Resuscitator [3]

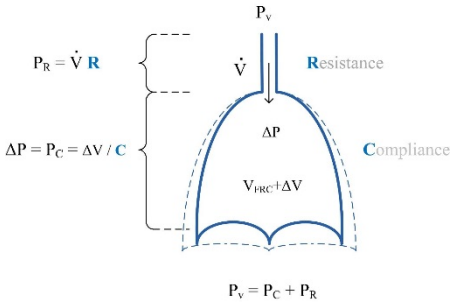

Figure 1.4 Single Compartment Lung Model [7]

2. Task Two

In this section, safety issues of computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET) is introduced respectively.

2.1 Safety Issue of CT

The main safety issue of CT is the radiation released while in scanning process. Essentially Speaking, CT imaging is applying X-ray to obtain information from all angles around interested region of body, reconstructing these information to a slice that shows the inter structure of body. In most cases, there is no necessary for patients to take contrast medium. But the radiation of X-ray brings high risk to patients and radiation workers, since high dose radiation that is accumulated in a period may increase the risk of cancer. To keep patient in safe level while scanning, the dose used in CT scanning should be at minimum level of effective function. This minimum dose is called effective dose. The typical values of effective dose expected for adults is shown in Table 2.1. Thus, use different effective dose when different part of body needs to be scanned. The scanned volume and time should be kept in minimum range to reduce absorbed dose. Pregnant and breastfeeding women, children and infants are more sensitive to the dose than other people. The annual occupational dose of radiation workers is 50 mSv that is the maximum allowable annual occupational dose [8]. In general, occasional CT scanning in low dose will not cause great influence to the body.

Examination	Effective dose (mSv)
Head CT	2
Chest CT	7
Abdomen CT	8
Pelvis CT	6
Coronary artery calcification CT	3
Coronary CT angiogram	16

Table 2.1 Effective Dose of CT [8]

2.2 Safety Issue of MRI

There are three safety aspects of MRI need to be concerned, which are attracting ferromagnetic, noise and excessive heating. Since MRI equipment provides a powerful magnetic field. Ferromagnetic objects can be attracted by a strong force. Patients or operators may be injured by the moving object. Some medical devices, such as hearing aid and pacemaker may be damaged by the strong magnetic field. Thus, before taking MRI exams, make sure that all ferromagnetic objects is removed by anyone who will step in MRI system room [9]. The noise produced by MRI system is really loud. Patients lie in a small chamber while being scanned with unpleasant mood. And the scanning time of MRI is pretty long, so that the noise may damage the hearing of patients. To reduce the noise, a simple way is that wearing an ear muff to protect hearing [10]. In some cases, MRI system may cause conductive materials excessive heating, for instance, coils and monitors. Since the concentration of currents of these objects is sufficient to generate heat. The heat may hurt patient who is undergoing the scanning process. To protect patients from excessive heating, it is guaranteed that no metal objects contacting patients' skin, and all devices in MRI system room should be thoroughly tested [11].

2.3 Safety Issue of PET

PET is a kind of functional imaging technology that is used to describe the metabolic status of body. Also, PET is the most effective way to detect tumor. The safety issue of PET is radiation releasing, which is the same as CT scanner. However, the dose given by PET is a small amount. Reduce exposure duration to avoid high absorbed dose. The other issue is that patient who scanned by PET needs to be inject radioactive drug before scanning. Usually, 18F-FDG, a glucose-like drugs, is the standard radioactive drug applied in PET scanning. If the patient has the irritability to this medication or the patient gets diabetes, it should be cautious to take advice from doctors. For patients who can safely inject the contrast medium, radioactivity decays rapidly that will not introduce other influence [12].

The comparison among CT, MRI and PET is shown in table 2.2. Each imaging technology has advantages and disadvantages. There is no best one for patients, but the most suitable way to obtain information.

Tech.	Invasive	Radiation	Contrast Medium	Other
CT	No	Yes	No (in most cases)	
MRI	No	No	No (in most cases)	Noise, Heat
PET	No	Yes	Yes	

Table 2.2 Comparison Among CT, MRI and PET

3. Task Three

3.1 Localize Impaired Coronary Artery

Impaired coronary artery can be located by many devices or tools, such as CT, MRI, X-ray machine and vascular endoscopy. The surgery is going to bypass the impaired coronary artery, in which surgeon will replace damaged artery by surrounding vessels. Thus, not only the location of impaired vessel, but also vessels near the coronary artery which are concerned in surgery process. Vascular endoscopy is able to observe the inner situation of artery, but it cannot obtain the information about vessel's position. Comparing with X-ray images, CT and MRI images have high resolution and can be reconstructed into three dimensional model. The impaired artery and positions of near vessels can be graphically presented in a three dimensional coordinate, which is useful to plan surgery. In clinical scenario, iodine contrast medium should be injected into veins firstly. After which, the chest part of patient is scanned by CT or MRI, generating a series of two dimensional images. Interested regions (vessels) are extracted by some image processing technologies to form into three dimensional structure. The structure can be applied to plan surgery as well as provide guidance during surgery process.

3.2 Monitoring during Surgery

During the surgery, several signs of patient are continuously monitored, including electrocardiogram (ECG), blood pressure, blood oxygen level and respiratory rate. The purpose of on-going monitoring is to respond as soon as possible if patient's signs appear deterioration. ECG can be measured by ECG amplifier. The ECG amplifier is composed of differential amplifier and band pass filter. Differential amplifier amplify the potential between different measurement points on patient's body and reduce common mode signal. Band pass filter is able to remove noise from original ECG signal, giving a high gain to the out ECG. After which, ECG signal is displayed on the screen. Heart beat rate can be calculated heart and cardiac cycle also can be observed by processing the signal.

Patient should be anesthetized before the bypass surgery being carried out. Thus, it's necessary to monitor patient's blood pressure that measured by invasive cannula needle. The needle is inserted in a vessel, so that blood pressure of patient is measured beat-by-beat. The other side of needle is connected to an amplifier and filter to improve measured signal, after which the signal is transferred into the monitor equipment.

The pulse oximeter has ability to measure blood oxygen level. Two kinds of wave are transmitted from pulse oximeter through the finger, they are red light and infrared. In blood, there are two types of hemoglobin, one is full of O_2 (HbO_2), the other one lacks of O_2 (Hb). HbO_2 can absorb more infrared rather than red light. On the contrary, Hb can absorb more red light than infrared. When O_2 level increases, concentration of HbO_2 also increases, more infrared and less red light will be received. When O_2 level decreases, concentration of Hb increases, causing more red light and less infrared are received. Thus, calculate the ratio between received red light's amplitude and received infrared's amplitude, generating the oxyhemoglobin saturation which is seen as oxygen level in vessel.

There are many ways to measure respiratory rate, for example, detecting movement of chest wall, analyzing acoustic signal of respiratory vibrations and measuring airflow. The other one method is to calculate respiratory rate from pulse oximeter, since after each breath, the oxygen level in blood will increase. And oxygen level decreases when patient exhale [13].

Acknowledgement

It's very grateful to Sabine and Cristina for your earnest attitude to every lecture and every assignment. I noticed you're on line all night. Amazing exam! Amazing semester!

Reference

[1] John Kattwinkel, Jeffrey M. Perlman, Khalid Aziz, Christopher Colby, Karen Fairchild, John Gallagher, Mary Fran Hazinski, Louis P. Halamek, Praveen Kumar, George Little, Jane E. McGowan, Barbara Nightengale, Mildred M. Ramirez, Steven Ringer, Wendy M. Simon, Gary M. Weiner, Myra Wyckoff, Jeanette Zaichkin, "Neonatal Resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care", American Academy of Pediatrics, 2010, vol.126 no.5, pp: e1400-e1413, doi: 10.1542/peds.2010-2972E.

[2] Steven C. LeCroy, "A Review of Neonatal & Infant Ventilation Methods - Comparison of self-inflating bags, flow-inflating bags & infant T-piece resuscitators", http://www.jems.com/, 2014.

[3] neoResus, "Key concepts and guidelines: First response interventions- Breathing", access date: 12/12/2016, http://www.neoresus.org.au/learning-module-1-first-response.-interventions-breathing/.

[4] Wikipedia, "Continuous positive airway pressure", access date: 14/12/2016, https://en.wikipedia.org/wiki/Continuous_positive_airway_pressure.

[5] EB Medicine, "Children Are Not Simply Little Adults", access date: 15/12/2015, https://www.ebmedicine.net/topics.php?paction=showTopicSeg&topic_id=204&seg_id=4196.

[6] Americo, "MANUAL RESUSCITATOR (AMBU BAG)", access date: 14/12/2016, http://americocorp.com/?product=americo-manual-resuscitator-ambu-bag.

[7] Ants Silberberg, "Respiratory system", slides for lecture, 26/9/2016.

[8] Cynthia H. McCollough, Jerrold T. Bushberg, Joel G. Fletcher and Laurence J. Eckel, "Answers to Common Questions About the Use and Safety of CT Scans", Mayo Clinic Proceedings, 2015, vol.90, no.10, pp: 1380-1392, doi: 10.1016/j.mayocp.2015.07.011.

[9] RadiologyInfo.org, "Magnetic Resonance Imaging (MRI) Safety", access date: 15/12/2016, http://www.radiologyinfo.org/en/info.cfm?pg=safety-mr#safety-considerations.

[10] EARPLAG, "Hearing Protection in MRI Procedures", access date: 15/12/2016, http://www.earplugstore.com/mri-safety-hearing-protection-information.html.

[11] MRIsafety.com, "Guidelines to Prevent Excessive Heating and Burns Associated with MRI", access date: 15/12/2016, http://www.mrisafety.com/SafetyInfov.asp?SafetyInfoID=166.

[12] Wikipedia, "Brain positron emission tomography", access date: 15/12/2016, https://en.wikipedia.org/wiki/Brain_positron_emission_tomography#cite_note-2.

[13] William Daw, Ruth Kingshott, Reza Saatchi, Derek Burke, Alan Holloway, Jon Travis, Rob Evans, Anthony Jones, Ben Hughes and Heather Elphick, "Medical Devices for Measuring Respiratory Rate in Children: a Review", Journal of Advances in Biomedical Engineering and Technology, 2016, vol.3 pp:21-27, doi: 10.15379/2409-3394.2016.03.01.04.