CONTEMPORARY DATA CAPTURE, ANAESTHESIA MONITORING AND POINT-OF-CARE TECHNOLOGY IN CRITICAL CARE RESEARCH SETTING FOR ANIMAL MODELS

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Introduction

In critically ill patients, there is a depression of vital body systems notably the cardiovascular, respiratory and nervous systems. These systems have to be continually monitored to ensure adequate blood flow to the patients’ tissues, adequate oxygen concentration in the patient’s arterial blood, and adequate ventilation. Often, in the critical patient, trends will mean more than individual measurements which underscores the importance of serial and chronic observations to give a more accurate indication of a patient’s physiological state.

As in humans, anaesthetised ill animals require meticulous critical care monitoring by trained and experienced professionals with the aid of contemporary patient monitoring devices in a well-equipped facility. Although animal patient monitors are designed to aid in determining priorities for monitoring, they are not meant to replace the veterinarian or technician. The measurements captured or derived from monitoring devices are a useful guide in showing trends happening within the fragile or disturbed physiology during experiments, even if they are not absolute values. Furthermore, most, if not all the devices were developed for human medicine, so they may be presumed to be accurate in taking measurements, but may not necessarily represent values of the animal model. It is thus important to continually examine the animal by thorough basic examination and not by monitors alone.

Critical care clinicians, research scientists and technicians often work with experimental animal models that require rapid and continuous capture of vital patient information using medical devices to enable critical monitoring for a variety of procedures and studies. The diversity of animal patient monitoring devices in terms of model, brand, type and configuration poses challenges; therefore, it should not be assumed that existing human patient monitoring devices are standard for animals as significant variations exist.

Technology for physiological and advanced haemodynamic monitoring at CCRG animal ICU

The majority of human ICU patients are kept anaesthetised under total intravenous anaesthesia (TIVA), likewise, all ovine models of critical illness at CCRG are maintained by TIVA. Broadly, the ICU hardware is classified into advanced haemodynamic & intensive care patient monitors, and auxiliary life support equipment.

Advanced haemodynamic & intensive care patient monitors

Cardiovascular, temperature, oxygenation and respiration/ventilation physiological variables are continually monitored by the Marquette Solar 8000. A pulmonary artery (PA) catheter is placed and coupled with a cardiac output monitor. Continuous cardiac output (CCO), mixed venous oxygen saturation (SvO2), end diastolic volume (EDV), systemic vascular resistance (SVR), body temperature (BT) and derived parameter monitoring commences using the Vigilance II monitor. Measured variables are recorded every five seconds using manufacturer provided software. Direct arterial blood pressure (ABP), central venous pressure (CVP), pulmonary artery pressure (PAP) measurements are transduced to the Marquette Solar 8000 monitor via respective attachments on the ports of the attachment from the PA catheter. The Marquette Solar 8000 monitor is also used for pulse oximetry (SPO2), ETCO2 recordings and electrocardiography (ECG).
**Auxiliary life support equipment.**

This comprises mechanical ventilators, patient heating sources, medical imaging, oxygen delivery, patient warming and point-of-care laboratory equipment (oximetry, blood gases, blood coagulation machines centrifuges and refractometers). Mechanical ventilation is achieved by the use of the Galileo intensive care ventilator which has advanced ventilation modes and drug nebulising capabilities. Patient heating is achieved by the use of a circulating warm water mattress attached to either the warm water pump cooler/heater.

**General discussion on monitoring technology**

Veterinary aids or devices are required for capturing data and monitoring body systems. Monitoring the critically ill patient is important because drug effects are less predictable and often more pronounced in stressed animals.\(^4\)\(^6\) Constant monitoring is essential to maintain the necessary level of analgesia/anaesthesia, maintain a free airway, and to be able to recognise and deal with complications promptly. The data captured from the monitored parameters using medical devices and how frequently this is done depends on the changing needs of the individual patient in critical care. This information is necessary for the critical care veterinarian to make a final decision regarding treatment changes if necessary. It is very important for the critical care veterinarian to continually review and interpret the results of monitoring in particular to decide on the urgency of a particular scenario for each experimental subject. It is vital to know the limitations of the method used, and what the data means. The collection of information without knowing why or what to do with it once it has been availed is counterproductive. For this reason the role of the critical care veterinarian is vital for observing and testing the known subjective assessments such as monitoring of central nervous system functions.

**Patient monitoring devices**

The emergence of all-in-one or multi-parameter patient monitors such as Marquette Solar 8000 that our group uses to monitor experimental animal patients may not be a common place in many animal ICUs. These devices have modular capabilities of continuous measurement and the monitoring of ECG, SPO\(_2\), ABP, CVP, ETCO\(_2\) and body temperature. The Marquette Solar 8000 monitor also has the capability of monitoring anaesthetic gases. In the veterinary market, multi-parameter patient monitors come in various makes and models with varying capabilities such as Surgivet\(^{TM}\), Mindray\(^{TM}\), Bionet\(^{TM}\), VetSpecs\(^{TM}\), Pace Tech\(^{TM}\), Cardell\(^{TM}\), Datascope\(^{TM}\) and Dicicare\(^{TM}\). We discuss the relevance of the individual modules below.

The ECG detects the electrical activity of the heart but not the cardiac function.\(^1\) This is important for monitoring cardiac rate and rhythm, the presence or absence of effective coronary blood flow, disturbances in potassium ion concentration and drug intoxication.\(^7\) In the event of cardiac arrest, asystole and fibrillation can be differentiated. An ECG however does not give any indication of cardiac output and whether problems arising originate within the heart or are due to extrinsic factors.\(^4\)\(^5\)

Adequate blood pressure is necessary for tissue perfusion which is determined by cardiac output. ABP is often monitored in the critical patient to provide information on cardiac output.\(^1\) There are two types of blood pressure measurements: invasive or direct blood pressure measurement (IBPM) and non-invasive or indirect blood pressure measurement (NIBPM). The accuracy of any device used to measure blood pressure is an important consideration when selecting monitoring equipment, the ANSI/AAMI SP10 standard has been widely cited in this respect in recent veterinary publications.\(^8\) A sphygmomanometer can be used for indirect manometry of arterial pressure by employing an inflatable cuff and a stethoscope. It is commonly used in conjunction with a Doppler flow probe. It is important for measuring systolic pressure and to a lesser extent diastolic pressure in animals.\(^1\)\(^9\) This simple method provides good comparative information of blood pressure. Commonly used oscillometric non-invasive blood pressure monitors include Cardell Veterinary Monitor 9401 BP (Sharm Veterinary Inc, Tampa, FL); and Datascope Passport, (Datascope Corp, Paramus, NJ).\(^10\) The Surgivet V60046 is also commonly used in non-invasive blood pressure measurement.\(^11\) The Marquette Solar 8000 monitor also has NIBPM capabilities. An example of ultrasonic non-invasive blood pressure monitor is the ultrasonic Doppler flow detector, Model 811-B (Parks Medical Electronics Inc, Aloha, OR).\(^10\)

We routinely measure and monitor direct ABP and CVP with the Marquette Solar 8000 monitor. CVP monitoring is useful in measurement of hydrostatic pressure in the intrathoracic vena cava which is a useful guide not only in fluid replacement therapy but also to the ability of the right heart to handle the venous return.\(^3\)
Direct blood pressure measurement is not without problems; clotting in the catheter can occur, time is required to instrument the patient, the electronic equipment is expensive and potentially fatal complications can occur.

Increasingly, echocardiography is now considered an indispensable tool for diagnosis and haemodynamic monitoring in critically ill patients. We also routinely monitor CCO, but some disadvantages have been reported.

A pulse oximeter is a device that measures the saturation of oxyhaemoglobin in blood and is one of the most utilised monitors in the critically ill or emergent patient. It also shows a pulse waveform, which, while not giving an actual measurement of the pulse pressure, does give the rate and some indication of its character. Accuracy and failure rates (failure to produce a reading) vary widely from model to model and from species to species. We get reasonably consistent oximetry signals in sheep by clamping the probe on the nasal pore or the lip. There are studies indicating that third generation pulse oximeters may not perform better than older instruments.

A capnograph analyses end-tidal carbon dioxide (ETCO₂) during breathing and gives valuable information on the ventilatory status of the patient. The ETCO₂ is a close approximation to arterial pCO₂ and therefore gives an indication of hypo- or hypercapnia. Capnography failures are usually associated with excessive fogging or fluid build-up within the breathing apparatus.

A stethoscope is an important aid in monitoring heart rate and can provide more than just heart rate.

Ventilation meters are used to measure respiratory tidal volume. There are various types; however, the most useful ones are Wright's Respirometer and the Dräger Volumeter. The associated problems are that they do not reveal the adequacy of distribution or of gaseous exchange in the lungs. Ventilation meters may add resistance to the airway and are only useful if one is not sure of the adequacy of the tidal volume after reversal of a muscle relaxant. Our patients are ventilated with the Galileo ventilator which has inbuilt ventilation meters and provides real time parameters for ventilation.

Performing regular patient-side monitoring tests of certain parameters is important critical care. The regular monitoring of PCV, refractometric TP, blood glucose, electrolytes, venous or arterial blood gas, clotting parameters and blood smear examination should be considered. Full blood panels for complete blood count (CBC) and biochemistry are required periodically as a benchmark. The analysis of blood gases (PaO₂, PaCO₂, and pH) is the most effective way of measuring respiratory efficiency. Handheld devices and standard chemistry analysers are available for use in blood gas analysis. The common handheld devices are the i-Stat and the lactate meter. There are various point-of-care or desktop blood analysers in use in emergency and critical care establishments. We use the bench top ABL800 FLEX blood gas analyser, which can measure up to 18 STAT parameters on the same blood sample including creatinine. Our group utilises the rotating pin thromboelastometry (ROTEM) to determine if bleeding is caused by haemorrhage or clotting factor deficiency, and the Multiplate platelet function analyser which uses impedance aggregometry to assess platelet function in whole blood.

A thermometer is used for measuring body temperature. Either rectal, oesophageal or core temperature may be monitored. There are also thermometers that are designed to detect body temperate in the external ear canal. For our animal models, continuous core temperature is monitored in real-time with the aid of the PA catheter and CCO monitor.

Mechanical ventilators

Mechanical ventilators are important aids of respiration during life support for example in the management of respiratory failure, cardiac arrest, neurologic impairment, and nonresponsive hypotension to perform some or all of the work of breathing. Ventilators are widely used in veterinary medicine to improve the survival of animals with hypoxaemic and hypercapnic respiratory failure. The indications, goals, and prognosis of mechanical ventilation in animals have been covered in detail elsewhere. The ventilator also acts as a ventilation meter, respiratory rate monitor and apnoea alarm.

Conclusion

Monitoring of critically ill patients is essential; failure to detect warning signs of impending disaster results in a dead or impaired patient. Even if the patient survives, there might be considerable visceral organ damage. Monitoring devices can be misleading if they do not function correctly or are not properly set up. Artefacts do
occur; it is therefore important for the veterinarian to physically check the patient first, before assuming the instrument is faulty. There is no device that replaces the veterinarian in monitoring an animal patient. Our monitoring practices probably represent an advanced and appropriate technology available during the provision of total intravenous anaesthesia in ovine models.

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**References**


