Monitoring of Patients in the ICU

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Introduction



- *The Intensive Care Unit (ICU), also known as the Critical Care Unit is defined by the Task Force of the World Federation of Societies of Intensive and Critical Care Medicine (WFISCCM) as*
  - *"an organized system for the provision of care to critically ill patients that provides intensive and specialized medical and nursing care, an enhanced capacity for monitoring, and multiple modalities of physiologic organ support to sustain life during a period of life-threatening organ system insufficiency."*
- *Mainly, the ICU's goal is to prevent a progressive deterioration in the physiologic state of a patient as the underlying disease is being managed.*
- *Intensive care units (ICUs) are vital for enhancing the survival of critically ill patients through the continuous monitoring and maintenance of their vital functions.*
- *Vital signs indicate the status of the patient's life-threatening functions in the ICU.*
- *Continuous monitoring of patients' vital signs or physiological functions aids in ensuring patient safety through awareness of critical changes in the patient's*

health status, and it guides daily therapeutic interventions.

- *Early recognition of patient deterioration and timely intervention are critical in saving patients' lives.*
- *Subtle changes in vital signs such as respiratory rate, blood pressure, heart rate, temperature and oxygen saturation are early signs of clinical deterioration that may eventually lead to adverse events.*
- *Through continuous monitoring of vital signs, clinical deterioration can be identified well in advance of any adverse events occurring. In order to recognize an acute change in a patient's physiology, their vital signs must first be accurately assessed.*

Vital Signs

The recommended vital signs are:

1. *heart rate (HR)*
2. *respiratory rate (RR)*
3. *blood pressure (BP)*
4. *oxygen saturation (SpO_2)*
5. *level of consciousness*
6. *temperature*

Be measured at a minimum but that the additional monitoring of

7. *pain.*
8. *urine output.*
9. *biochemical analysis.*

Blood pressure

- *Blood pressure (BP) can be defined as the pressure exerted by the circulatory blood on the arterial walls.*
- *It provides an important reflection of the blood flow when the heart is contracting (systole) and relaxing (diastole).*
- *Three values are considered when measuring BP: systolic (SBP), diastolic (DBP) and mean (MBP) pressure.*
- *SBP indicates the peak pressure attained during the cardiac cycle.*

- *Mean arterial pressure (MAP) is defined as the mean pressure during the cardiac cycle and is an important parameter during resuscitation procedures.*
- *The difference between SBP and DBP is known as the pulse pressure (PP) and determines the peripheral palpability of the arterial pressure wave (for example at the radial or femoral site).*

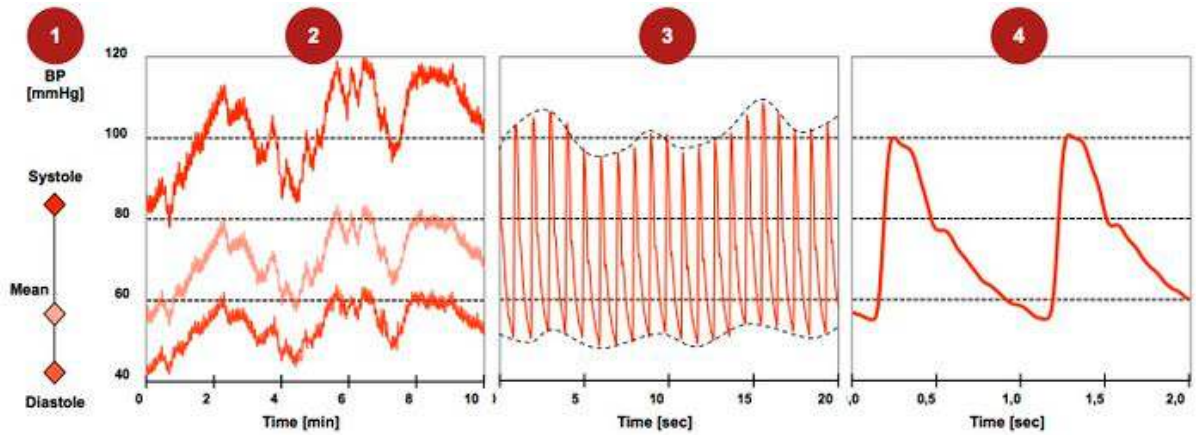
Normative BP values :

Parameter	***Normal range***
Systolic blood pressure (SBP)	*90-140 mmHg*
Diastolic blood pressure (DBP)	*60-90 mmHg*
Mean arterial pressure (MAP) *[SBP + (2 x DBP)]/3*	*70-105 mmHg*
Right atrial pressure	*2-6 mmHg*

- *Alterations in BP can be reflective of underlying pathologies or of the body's attempts to maintain homeostasis.*
- *A decrease in BP is often seen in patients prior to cardiac arrest.*
- *Hypotension can also lead to inadequate perfusion of the vital organs.*
- *During hypertension, the myocardial workload is increased and it can therefore precipitate cerebral vascular incidents (CVI).*
- *BP can be measured non-invasively using a sphygmomanometer (BP cuff) but it is often measured invasively using arterial lines which are generally inserted in large blood vessels such as the radial or femoral artery.*
- *Data from intra-arterial catheters are considered more reliable and provides continuous BP monitoring while also*

allowing the easy collection of arterial blood (to assess blood gas and acid-base analysis) without further peripheral puncturing.

- *Another invasive method of measuring BP is through a central venous pressure (CVP) line where the tip of the catheter is positioned close to the right atrium.*
- *The internal jugular and subclavian veins are often used when inserting a CVP line. The CVP line reflects right atrial filling pressure and helps with the assessment of intraventricular volume and right-sided heart function.*
- *There are many factors with the ability to influence BP, these include:*
    - *Nicotine*
    - *Pain*
    - *Position of the patient*
    - *Medication*
    - *Alcohol*
    - *Illicit drugs*
- *BP is also influenced by*
    - *cardiac output,*
    - *peripheral vascular resistance,*
    - *blood volume and viscosity*
    - *vessel wall elasticity.*



Blood Pressure Graph

Respiratory rate

- *Respiratory rate (RR) refers to the number of breaths as calculated over one minute, with a normal RR being 12-20 breaths per minute.*
- *A rise in RR is the most sensitive indicator of clinical deterioration and impending adverse events such as cardiac arrest or death.*

Terminology	***Definition***
Tachypnoea	*Abnormally quick RR (>20 breaths/minute)*
Bradypnoea	*Abnormally slow RR (<12 breaths/minute)*
Dyspnoea	*Difficulty with breathing*
Orthopnoea	*Difficulty breathing necessitating an upright sitting position to alleviate*
Hypoxia	*Insufficient oxygen at a cellular level*
Hypoxaemia	*Low levels of oxygen in the blood*
Anoxia	*Lack of oxygen*

- *Tachypnoea refers to a rate of more than 20 breaths per minute and is a sign of respiratory distress.*
- *During bradypnoea, the RR is less than 10 breaths per minute and is often caused by drugs (e.g. opioids), hypothermia, fatigue or central nervous system depression.*
- *A RR of more than 24 breaths per minute is considered a medical emergency as it indicates the possibility of respiratory failure.*
- *While the measurement of RR is vital, it is also important to assess:*
    - *Respiratory effort - including depth of inspiration, use of accessory muscles and the sound of breathing (noisy breathing is indicative of an increased workload in breathing)*
    - *Chest movement - is it equal, bilateral and symmetrical Pattern/rhythm of breathing*



Tracheostomy with tube

- *The inability to breathe spontaneously inevitably leads to the need for mechanical ventilation(MV).*
- *MV is an essential supportive treatment for critically ill patients and is a frequent occurrence in the ICU.*
- *It is connected to the patient through the use of an endotracheal tube or a tracheostomy tube via a closed circuit.*
- *Ventilators are classified based on the methods utilized to cycle between the inspiratory and the expiratory phases. These include the:*
    - *Pressure control mode - the inspiratory pressure is set, the rate is set and the volume is dependent on the patient's lung compliance*
    - *Volume control mode - the tidal volume is pre-set, the rate is set but the peak inspiratory pressure varies depending on the patient's degree of lung compliance*
- *It is important to be aware of the ventilator modes frequently used. These are described in Table below.*

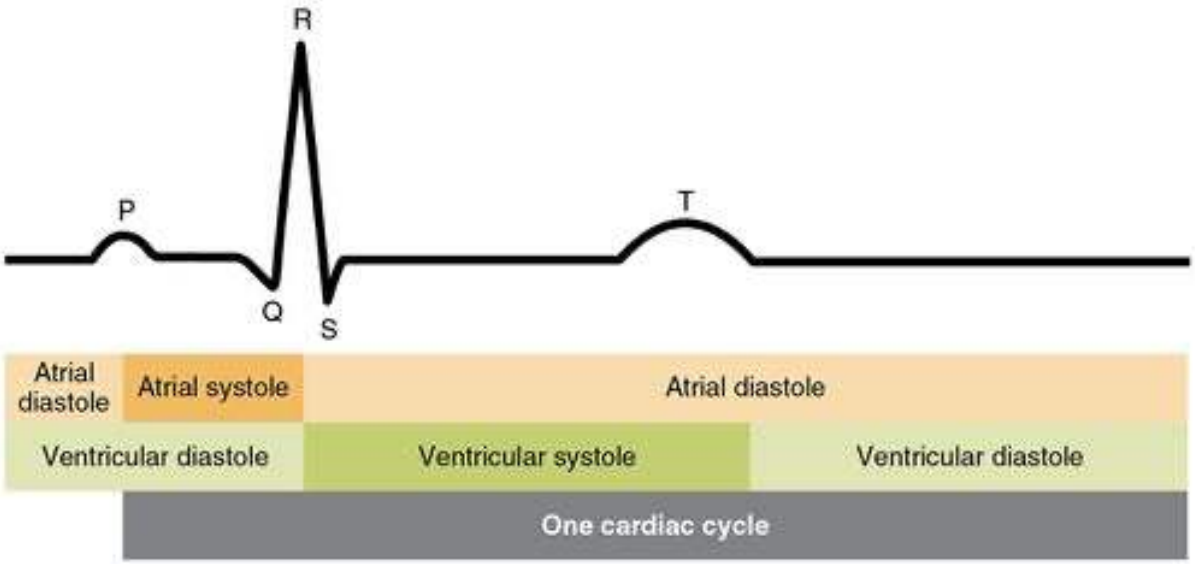
Table 3. Mechanical ventilator modes

Ventilator mode	***Description***
SIMV *(Synchronised intermittent mandatory ventilation)*	*Delivers pre-set volume or pressure at a pre-set rate and it is synchronised with the patient's own respiratory effort* *Volume or pressure cycled* *Most commonly used ventilator mode* *Can be used as a weaning mode*
CMV *(Controlled mandatory ventilation)*	*Delivers gas at a pre-set volume and rate is not synchronised with spontaneous breaths*
PSV *(Pressure support ventilation)*	*A pre-set inspiratory pressure enhances the spontaneous breaths of the patient* *The rate and volume of the ventilation is controlled by the patient*
PC *(Pressure control ventilation)*	*Gas is delivered at a pre-set rate and inspiratory pressure, and volume is dependent on the patient's lung compliance*
BIPAP *(Bilevel positive airway pressure)*	*Pressure-controlled ventilation that allows spontaneous breaths from the patient anywhere in the cycle* *Provides high and low positive end-expiratory pressure*
CPAP *(Continuous positive airway pressure)*	*Provides constant positive airway pressure in spontaneous mode (often seen with PSV)* *Promotes the exchange of gasses through the opening of alveoli and by increasing the functional residual capacity*
PEEP *(Positive end-expiratory pressure)*	*Same principle as CPAP but in a non-spontaneous mode*

Pulse

- *Pulse is defined as "the palpable rhythmic expansion of an artery produced by the increased volume of blood pushed into the vessel by the contraction and relaxation of the heart".*
- *It reflects both the circulating volume and the strength of contractility.*
- *There are many factors that can impact the pulse of a patient, including:*
    - *Age*
    - *Medication (e.g. beta-blockers)*
    - *Existing medical conditions (e.g. fever)*
    - *Fluid status (hyper/hypovolaemia)*
- *Pulse incorporates more than just heart rate, which is the measurable characteristic of the pulse.*
- *When palpating pulse, the strength/amplitude of the pulse, regularity of the pulse and the peripheral equality of pulses should also be considered.*
- *Many of the characteristics of the pulse are monitored using an electrocardiograph (ECG) which is essential in diagnosing cardiac rhythm disorders.*
- *The incidence of cardiac arrhythmias is as high as 40% in patients in the ICU and can be attributed to*
    - *electrolyte imbalances,*
    - *metabolic disturbances,*
    - *invasive lines,*
    - *multiple drug therapy and*
    - *quick changes in their intravascular volumes.*
- *The bedside cardiac monitor (oscilloscope) in the ICU provides a continuous display of not only the patient's ECG, which includes heart rate (measured as the number of QRS complexes) and rhythm, but also the oxygen saturation (SpO_2).*
- *Continuous ECG monitoring facilitates quick identification of arrhythmias and therefore staff can promptly respond to such events.*

- *The 3- or 5-lead ECG provides easy attachment and immediate information about the electrical activity of the heart, but the 12-lead ECG provides a more accurate assessment.*
- *Heart rate is reflected by the number of QRS complexes in a minute (QRS rhythm) and a rate of 60-100 beats per minute (bpm) is considered to be within normal limits.*
- *In order to detect any abnormalities in rhythm, it is recommended that the HR be assessed for a full 60 seconds.*
- *Definite arrhythmias are diagnosed based on an ECG, but arrhythmias can be broadly classified into two groups based on heart rate.*
- *These include tachycardias (HR > 100 bpm) and bradycardias (HR < 60 bpm).*



The Cardiac cycle vs the Electrocardiograph

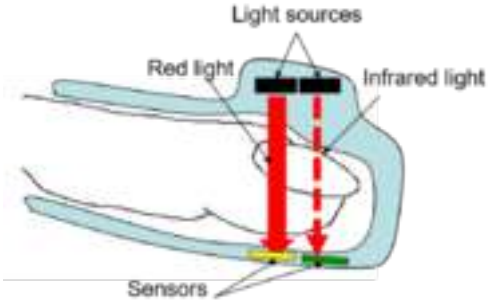
Oxygen saturation/pulse oximetry

- *Pulse oximetry is the technique used to measure arterial oxygen saturation in the peripheral blood vessels.*
- *It can be defined as "the ratio between oxygenated haemoglobin and the total amount of haemoglobin" in the blood and is expressed as SpO_2.*
- *An SpO_2 of 95-100% is considered within normative ranges. An SpO_2 of less than 90% is of grave concern.*

- *It is an easy, painless, non-invasive method whereby a probe is placed on the fingertip or earlobe to measure the oxygen saturation indirectly.*
- *A fall in SpO_2 indicates the development of hypoxaemia long before any visual evidence of cyanosis (SpO2 of 80-85%) becomes evident.*
- *Various factors influence the accuracy of pulse oximetry and these include:*
    - *Movement of the patient*
    - *Incorrect positioning of the probe*
    - *Hypothermia*
    - *Hypovolaemia*
    - *Vasoconstriction*
    - *Nail polish - as it absorbs the light waves used to measure SpO_2*



Pulse Oximeter



Mechanism of pulse oximetry

Temperature

- *Body temperature is represented by "the balance between heat produced and heat lost (thermoregulation)".*
- *Clinically, three types of body temperature have been described:*

    - *Patient's core body temperature*
    - *Patient's report on how they feel*
    - *Surface body temperature/how the patient feels to touch*
- *Temperature can be affected by many factors, including*
    - *the underlying pathophysiology (e.g. infection or sepsis),*
    - *skin exposure (e.g. in the operating theatre), age.*
- *The site where the temperature is measured can also be affected by local factors such as*
    - *the oral temperature immediately after consumption of hot/cold beverages.*
- *It is therefore important to consider not only proper calibration of the measuring device but also the variation of core temperature between different anatomical sites.*
- *Documentation of the site of measurement together with the measured temperature is essential for the accuracy of the measurement.*
- *Core thermometers (located on catheters and probes inserted into the pulmonary artery, oesophagus, bladder or rectum) are considered to be more accurate than peripheral thermometers (oral, axillary, temporal artery, tympanic membrane) and preferred in critically ill patients.*
- *Normal body temperature in healthy individuals is considered to be 36.8°C ± 0.4°C (measured in the oral cavity) with normal circadian variations of 0.5°C.*
- *Clinically, temperatures of 33-36°C are considered as mild hypothermia, 28-32°C as moderate hypothermia and below 28°C as deep hypothermia, whereas any temperature above 38.3°C (100.94°F) is considered a fever/hyperthermia.*
- *A cool skin temperature can also be indicative of poor peripheral perfusion (a circulatory problem) and the capillary refill time (CRT) (normative <2 secs) should therefore also be assessed.*

Level of consciousness

- *Level of consciousness (LOC) is the single most important indicator of cerebral functioning.*
- *It can be defined as the "degree of arousal and awareness" of a patient.*
- *In the critically ill patient, the LOC is most commonly assessed using the Glasgow Coma Scale (GCS) but the simpler AVPU rapid neural assessment method can also be used:*
    - ***A**lert*
    - *Responsive to **V**erbal stimulation*
    - *Responsive to **P**ainful stimulation*
    - ***U**nresponsive*
- *The GCS assesses two aspects of consciousness, namely:*
    - *Arousal/Wakefulness*
    - *Patient awareness in demonstrating an understanding of what a practitioner said through the ability to complete tasks*
- *A GCS score of less than 12 is considered concerning and a patient with a score of less than 9 will probably require airway intervention and intubation.*
- *A reduction of 2 points on the GCS is considered significant in indicating clinical deterioration of the patient.*
- *A patient's LOC or mental status can be affected by several factors including side effects of some medications (sedatives or analgesics, e.g. benzodiazepines, anxiolytics, opioids), hypoxia, hypercapnia, hypoglycaemia, hypotension, alcohol, cerebral pathology, etc.*

Pain

- *Critically ill patients in the ICU frequently experience acute pain.*
- *Many factors can lead to pain in the critically ill patient, including*
    - *surgical and post-traumatic wounds,*
    - *prolonged immobilisation,*

        - *the use of invasive monitoring devices and mechanical ventilators,*
        - *routine nursing care (for example, changing dressings).*
- *Patients experience pain differently, but the physiological consequences of inadequately managed pain are predictable and potentially harmful.*
- *Physiological responses to pain include increases in RR, HR and BP.*
- *Pain also increases patients' anxiety and leads to sleep disturbances which will affect the optimal recovery of the patient.*
- *Pain can incur functional limitations such as impaired mechanics of the pulmonary system and delayed ambulation which could lead to higher morbidity in critically ill patients.*
- *Assessment of pain is therefore vital for patient recovery and improved functional outcomes.*
- *Tools for the assessment of pain in the ICU include the numeric pain rating scale, the analogue scale, the behavioural pain scale and the critical care pain observation scale.*
- *A heightened sympathetic activity like hypertension, increased heart rate and restlessness can be indicators of pain in heavily sedated or paralyzed patients.*
- *Physiotherapy treatment can also be hampered by pain in that patient participation is reduced and mobilisation is limited.*
- *Early proactive steps should therefore be taken to address the patient's requirements for analgesia before the commencement of physiotherapy treatment.*
- *Pain can be managed with analgesics together with physiotherapeutic modalities.*
- *Physiotherapeutic interventions for pain do not aim to be a substitute for analgesic medication, but rather aim to reduce the total dose of analgesic medication needed to reduce their unavoidable side effects.*

Urine output

- *Even though urine output is an indicator of renal perfusion, it is frequently used as an indicator of cardiac output (25% of cardiac output perfuses the kidneys).*
- *Normal urine output in adults is at least 0.5 ml/kg/h, which also signals adequate renal perfusion.*
- *With urine output of less than 500ml in 24 hours, the kidneys are unable to excrete the waste products of metabolism which can result in uremia, metabolic acidosis and hyperkalaemia.*
- *A drop in urine output may be the first clinical indicator of fluid and electrolyte imbalance and is considered an early sign of hypovolaemia.*
- *When cardiac output falls so does renal perfusion, ultimately leading to renal failure.*

The parameters for urinary output disorders can be found in Table below:

Urinary Output condition	***Parameters***
Anuria	*<50ml urine in 24 hours*
Oliguria	*<400 ml urine in 24 hours [<0.5ml/kg/h]*
Polyuria	*>3000 ml urine in 24 hours*
Dysuria	*Painful micturition*

Summary

- *It is essential to initiate early mobilisation and physical rehabilitation in critically ill patients to ensure better outcomes for the patient.*
- *But it is also known that changing patient position causes changes in their haemodynamic balance.*
- *Changes in vital signs are often the first indicators of clinical deterioration of the patientand play an important role in informing the most appropriate course of treatment to pursue.*

- *It is therefore essential for physiotherapists to closely monitor and interpret the vital signs of patients to guide their treatment and if necessary, to quickly intervene or alert the rest of the ICU team when alarming rapid changes occur.*
- *Close and continuous monitoring by the physiotherapist during and immediately after mobilization is essential for patient safety as clinically stable patients can potentially become unstable during and/or after mobilization.*