Monitoring - what is necessary, useful and futile?

Dr Anitha Shenoy

Professor of Anesthesiology
Kasturba Medical College, Manipal

INTRODUCTION

The way anaesthesia is administered to patients has changed over the years since the time it was first demonstrated in 1846. The art of anaesthesia has changed to more of science. Similarly, the patients and public are more aware of anaesthesia. They are more informed, expectations are high and are much more unforgiving. Errors, especially serious ones will no longer be taken as God's will. Liabilities are higher and the need to be alert and appropriate is ever present.

Monitoring of a patient is an integral part of present day anaesthesia. Many of the vital physiological processes can be measured and monitored. The extent of monitoring depends on the patient, procedure and facilities available at the hospital. Standards of monitoring have been laid down by various organisations of every country. They are mostly similar in their essence.

PURPOSE OF MONITORING

Anaesthesia and surgery can alter the patient's physiology. The purpose of surgery is to relieve an ailment and it is reasonable to expect the patient to return to the same condition as before surgery or may be even better postoperatively. Monitors can be used to measure the baseline status of the patient and then to follow the trends. Monitors are most often used to monitor physiological functions of the patient. They may also be used to monitor other equipment.

MONITORING PATIENT: WHAT IS MANDATORY?

The Indian Society of Anaesthesia has also laid down minimum monitoring standards based on the recommendations of the International Task Force and to suit the Indian conditions. The recommendations are as follows:

The anaesthesiologist

It is important to note that the most important monitor is the anaesthesiologist. Monitors are only machines and the data displayed by monitors need to be interpreted appropriately by the anaesthesiologist. For e.g., the monitor may display presence of ventricular fibrillation but it could be due to shivering artifacts or some other disturbance, the physician can analyse. Monitors simply cannot replace a physician.

It is mandatory that every anaesthetic is administered by only a qualified anaesthesiologist. It is required that the hospital management must make a qualified anaesthesiologist available for every case done under anaesthesia, be it, general, regional or monitored anaesthesia care. The anaesthesiologist must be present throughout the procedure and shift the patient to the postoperative care area or intensive care as required.

If the primary anaesthesiologist cannot be present throughout for any reason, the patient and his condition may be handed over appropriately to another qualified anaesthesiologist before he leaves.

In addition, since anaesthesia and surgery can be associated with sudden and drastic changes in the physiology of the patient, and that the anaesthesiologist may need help in dealing with such critical situations, an additional anaesthesiologist, trained anaesthesia technician, paramedic or a nurse who knows about these critical conditions and their management must be made available.

Physiological monitors

Although traditionally, anaesthesia was administered and monitored using hand on pulse and clinical observation of colour and chest movements, it is now mandatory to use some kind of electronic monitoring for patients. It is mandatory for every patient's oxygenation, ventilation and circulation to be continuously monitored. The following are considered minimum monitoring standards (what is necessary):

Oxygenation

Monitoring of colour of the skin, surgical field and watching out for cyanosis is not sufficient to detect hypoxia. Oxygenation of the patient must be continuously monitored using a pulse oximeter, which not only displays the oxygen saturation and heart rate but must also have a variable pitch and low oxygen saturation alarm. The use of a pulse plethysmogram is optional.

Ventilation

Ventilation may be monitored using auscultation of breath sounds, observation of chest movements, and movements of reservoir bag if the patient is breathing spontaneously. It is preferable to use a capnograph to monitor ventilation but it is not mandatory. Capnographs also help in confirming correct placement of artificial airways such as laryngeal mask airway and endotracheal tube. Expired volume monitors are useful. If the patient is being ventilated using a mechanical ventilator, a disconnection alarm to detect accidental disconnections is necessary.

Circulation

'Hand on pulse' was mandatory for anaesthesiologists in training 15 – 20 years ago but this habit is disappearing fast among the younger generation. While 'hand on pulse' is a good monitor, this alone is not sufficient or sensitive to detect cardiovascular events. Blood pressure must be measured at least every five minutes. Heart rate must be displayed continuously and recorded every five minutes. It is mandatory to use electrocardiogram to monitor for arrhythmia and ischaemia.

Temperature

A method of measuring temperature must be available. Mercury thermometers are limited by their inability to measure low temperatures, the minimum being 96°C. Thermistors are best suited to measure lower body temperatures.

MONITORING PATIENT: WHAT IS USEFUL?

Arterial blood gas analysis

A pulse oximeter displays only oxygen saturation of blood and is able to provide early and real time warning about hypoxia. However, it is not sufficient to monitor oxygenation status when a patient is breathing high concentrations of oxygen. When the oxygen requirement is high, it may be necessary to monitor oxygenation status by periodic assessment of partial pressure of oxygen in arterial blood. An arterial blood gas analysis is also necessary to measure pH and arterial carbon dioxide tension. Measurement of pH is necessary to evaluate acid-base status.

Invasive arterial pressure

Invasive arterial pressure monitoring is useful and in many situations, considered mandatory when beat to beat monitoring arterial pressure is required. These may be anaesthesia for special situations such as cardiovascular and thoracic procedures, procedures associated with major haemodynamic changes or fluid shifts and in patients with major cardiovascular co-morbidities. It is also necessary when potent cardiovascular drugs such as inotropes, vasopressors or vasodilators are required.

Central venous pressure

Monitoring of central venous pressure is useful for anaesthesia for special situations such as cardiovascular and thoracic procedures, procedures associated with major haemodynamic changes or fluid shifts and in patients with major cardiovascular co-morbidities. In addition, they may be used when peripheral intravenous access is not available, long term antibiotic use or chemotherapy is expected or the patient is in need of potent vasoactive drug infusion.

Pulmonary artery pressure

Pulmonary artery (PA) catheter insertion and interpretation of data is useful mostly in cardiac surgery. Even in cardiac surgery, it is often limited to patients with left ventricular dysfunction, especially if transoesophageal echocardiography is available. PA catheters capable of measuring pulmonary capillary wedge pressure and pulmonary arterial pressure only are available. Addition of a thermistor at its tip gives it the capability of measuring cardiac output by thermodilution method.

Cardiac output

Measurement of cardiac output, either continuous or intermittent using a pulmonary artery catheter is limited to cardiac surgery. However, with the advent of less invasive cardiac output monitors such as Flotrac or oesophageal Doppler, measurement of cardiac output for guiding fluid responsiveness in increasingly used for surgeries associated with major fluid shifts. Their usefulness in influencing outcome is yet to be proven.

Anaesthetic gas analysers

The concentration of anaesthetic gases in the inspired and expired gases can be measured and displayed continuously. Although there are several methods of measurement, infrared analysers are most useful. The gases from breathing system are continuously aspirated by a side stream method and analysed inside

the monitor. The monitor contains algorithms to display minimum alveolar concentration of anaesthetic. This is very useful in titrating anaesthetics, especially when low fresh gas flows are used. This may be a very useful tool to avoid awareness under anaesthesia. A record of these values may also be useful in the event of lawsuits against anaesthetist.

Depth of anaesthesia monitors

Gauging the depth of anaesthesia has largely remained an art. Great reliance has been placed on clinical parameters such as heart rate, blood pressure, sweating and tearing indicative of sympathetic response to detect awareness, particularly if the patient is paralysed. Movement of the patient is useful in spontaneously breathing patients. Anaesthetic gas analyser is useful in measuring concentration of anaesthetic delivered to the patient. More objective monitoring of depth of anaesthesia based on electroencephalogram can be done using BIS index monitor or entropy. These monitors actually measure the effect of anaesthetics on the brain rather than merely display anaesthetic concentrations. Thus they are more likely to be useful as indicators of depth of anaesthesia. These monitors display numbers 0 – 100, where in 40 – 60 is considered adequate anaesthesia, < 40 is deep anaesthesia and > 60 is light anaesthesia. These monitors can be influenced by other factors such as hypothermia and are not entirely accurate. Their role in influencing outcome is also not proven.

Transoesophageal echocardiography

Transoesophageal echocardiography is most useful in cardiac surgery for early detection of left ventricular dysfunction, assessment of adequacy of valve repairs, evaluation of ventricular filling, effusions and tamponade etc. Visual and real time assessment of the ventricular and valvular function is much more informative than indirect measurements such as chamber pressures. This information may be more useful to the surgeon for decision making. However, the equipment is very expensive and special training is required to obtain the correct images and interpret them limiting their routine use.

Mixed venous oxygen saturation

Continuous or intermittent monitoring of mixed venous oxygen saturation (if pulmonary artery catheter is in-situ) or central venous oxygen saturation (obtained through a special central venous catheter) is useful to titrate therapy in patients in septic shock. This is part of the surviving sepsis guidelines.

To understand the usefulness of central venous oxygen saturation, reference may be made to Fick's equation. Fick's equation states that the cardiac output is equal to the total oxygen consumption divided by arteriovenous oxygen content difference. It may be written as follows:
$CO = VO_2 / C\ (a – v)\ O_2$, where CO represents cardiac output, VO_2 = oxygen consumption,
$C(a – v)O_2$ = Arteriovenous oxygen content difference.

SvO_2 can be used to derive cardiac output when oxygen consumption is normal and constant. It can be used to monitor oxygen extraction ratio which is the ratio of oxygen consumption and delivered oxygen. The normal oxygen extraction ratio is 20 - 25%. The critical oxygen extraction ratio is 70% in normal individuals, below which anaerobic metabolism will occur. This corresponds to a venous oxygen saturation of 30% ($SvO_2 = 1 – ER$). One cannot survive for more than a few minutes to an hour with venous oxygen saturation less than this value.

In critically ill patients, this critical oxygen extraction ratio may fall to 50%, corresponding to SvO_2 < 50%. Thus, SvO_2 may be interpreted as follows:

> 70% - Normal
< 40 - 50% = Low, correct immediately
< 30% - Death imminent
50 – 70% - Interpret after correlation with clinical picture

When low venous oxygen saturation is seen, the cardiac output, haemoglobin or arterial oxygen saturation have to reviewed and optimized. Attempts may be made to reduce oxygen demand or consumption by sedating or paralysing the patient.

Measurement of venous oxygen saturation can be used to guide therapy in the perioperative period. Reduced oxygen saturation may be due to reduced oxygen delivery due to factors such as alveolar hypoxia, anaemia, hypovolaemia or heart failure. It may also be due to increased oxygen consumption due to factors such as pain, agitation, pyrexia, shivering or respiratory failure. Any intervention used to improve venous oxygen saturation requires clear understanding of the pathophysiology of such a change in that patient. Judicious use of venous oxygen measurements can be made to improve perioperative management and outcome.

Mixed venous oxygen saturation gives a better idea about global oxygen consumption but requires insertion of pulmonary artery catheter. $ScvO_2$ generally overestimates SvO_2 by 3 – 8%, since the blood from coronary sinus as well as inferior vena cava may not have mixed with the superior vena caval blood sample. However, if the tip of the central venous catheter is in the right atrium, $ScvO_2$ overestimates SvO_2 by only 1% and is an excellent surrogate of SvO_2.

Whether SvO_2 needs to be measured continuously or intermittently depends on clinical picture of the patient. If the patient is very unstable and is in septic shock, it may be more useful to have continuous measurement of SvO_2 ($ScvO_2$) whereas when the patient is more stable, intermittent measurement may suffice.

Defibrillator

A defibrillator must be available at every hospital and is considered essential resuscitation equipment.

MONITORING EQUIPMENT

Oesophageal stethoscope

This is a long tube similar to a nasogastric tube but with a noninflatable balloon at the tip. It is inserted blindly into the oesophagus either through the mouth or nose in an anaesthetised patient. The proximal end of the tube has a stethoscope which can be used to listen to both heart and breath sounds. It is very

useful when there is no access to the chest during surgery for auscultation, especially where power outages are common and no other monitoring is possible.

Precordial stethoscope

This is an ordinary stethoscope fitted with along tubing. This is commonly used in infants and children but can be useful in adults also. The diaphragm is taped on to the precordium so that the heart and breath sounds can be auscultated simultaneously. It is very useful when there is less access to the chest during surgery for auscultation, especially where power outages are common and no other monitoring is possible.

Oxygen analysers

The Indian society of anaesthetists recommends that anaesthesia machines should have hypoxic guard where in delivery of not less than 25% oxygen at all times can be ensured. If anaesthesia machines without hypoxic guard are being used, an oxygen analyser must be used to guard against delivery of hypoxic mixture to patients.

Airway pressure monitors

Airway pressure monitors must be used mandatorily to detect ventilator disconnection when mechanical ventilators are used to ventilate patients under anaesthesia. A continuous display of the peak and mean airway pressure is very useful in assessing the compliance and resistance of the respiratory system. Any change in the airway pressure due to surgery or comorbid disease can be detected early and treated appropriately. The effectiveness of the treatment can also be monitored.

Tidal volume monitors

Monitoring the tidal volume along with airway pressure provides more useful information about the condition of the respiratory system. When mechanical ventilators capable of providing pressure controlled ventilation are used, changes in delivered tidal volume due to changes in airway resistance and compliance must be monitored. Any change in the airway pressure due to surgery or comorbid disease may be detected early and treated appropriately. The effectiveness of the treatment can also be monitored.

MONITORING: WHAT IS FUTILE?

A monitor should not be used only because it is available and it is possible to use it. Every monitor can be useful provided it is used correctly. Any monitoring is futile if there is no indication to use it, the user is not familiar with its use or wrong values are followed. If risk-benefit analysis is done for every monitor used on a patient, no monitoring is futile. Furthermore, it can be stated that all monitoring can turn to be futile if the most important monitor, the anaesthesiologist is not present, present but not vigilant or present, vigilant but does not know how to react to a given critical situation. A monitor cannot simply replace a physician.

SUMMARY

Every anaesthetic begins with monitoring and ends with monitoring, the intent being to keep the patient safe through the stress of surgery and anaesthesia. It helps to detect and treat appropriately any altered physiology due to disease and surgery. The anaesthesiologist is the most important monitor and 'eternal vigilance' describes what he/she does during most of the anaesthetic. While some monitoring is mandatory, it can and should be escalated to be appropriate and proportionate to the condition of the patient.