



University of Dundee

Recommendations for standards of monitoring during anaesthesia and recovery 2021

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Published in:
Anaesthesia

DOI:
[10.1111/anae.15501](https://doi.org/10.1111/anae.15501)

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

[Link to publication in Discovery Research Portal](#)

Citation for published version (APA):

Klein, A. A., Meek, T., Allcock, E., Cook, T. M., Mincher, N., Morris, C., Nimmo, A. F., Pandit, J. J., Pawa, A., Rodney, G., Sheraton, T., & Young, P. (2021). Recommendations for standards of monitoring during anaesthesia and recovery 2021: Guideline from the Association of Anaesthetists. *Anaesthesia*. <https://doi.org/10.1111/anae.15501>

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Guidelines

Recommendations for standards of monitoring during anaesthesia and recovery 2021

Guideline from the Association of Anaesthetists

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Summary

This guideline updates and replaces the 5th edition of the *Standards of Monitoring* published in 2015. The aim of this document is to provide guidance on the minimum standards for monitoring of any patient undergoing anaesthesia or sedation under the care of an anaesthetist. The recommendations are primarily aimed at anaesthetists practising in the UK and Ireland, but it is recognised that these guidelines may also be of use in other areas of the world. Minimum standards for monitoring patients during anaesthesia and in the recovery phase are included. There is also guidance on monitoring patients undergoing sedation and during transfer. There are new sections specifically discussing capnography, sedation and regional anaesthesia. In addition, the indications for processed electroencephalogram and neuromuscular monitoring have been updated.

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Accepted: 13 April 2021

Keywords: depth of anaesthesia; monitoring - intra-operative; neuromuscular blockade

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Recommendations

- 1 Adequate supervision** requires that an anaesthetist should be present throughout the conduct of anaesthesia or the administration of procedural sedation*
- 2 General anaesthesia** requires minimum monitoring of ECG, SpO₂, NIBP and capnography, which should be checked for correct function and begun before induction of anaesthesia and continue throughout anaesthesia, transfer to the post-anaesthesia care unit (PACU) and recovery. Age-adjusted minimum alveolar concentration (MAC) should be monitored during use of inhaled anaesthetic drugs. Capnography should be continued until any artificial airway is removed and a response to verbal contact re-established.
- 3 Regional anaesthesia** requires minimum monitoring of ECG, NIBP and SpO₂ which should begin before the procedure, and should be continued for at least 30 min after block completion.
- 4 Procedural sedation** requires minimum monitoring of ECG, SpO₂ and NIBP. Capnography should be used during procedural sedation whenever there is loss of response to verbal contact.
- 5 Transfer** requires minimum monitoring of ECG, SpO₂ and NIBP. If an airway device remains in place capnography should be used during the transfer of anaesthetised or sedated patients, including from the operating theatre to the PACU.
- 6 Quantitative neuromuscular monitoring** should be used whenever neuromuscular blocking (NMB) drugs are administered, throughout all phases of anaesthesia from before initiation of neuromuscular blockade until recovery of the train-of-four ratio to > 0.9 has been confirmed.
- 7 Processed electroencephalogram (pEEG) monitoring** should be used when total intravenous anaesthesia (TIVA) is administered together with a NMB drug. It should start before induction and continue at least until full recovery from the effects of the neuromuscular blockade has been confirmed. It should be considered during other anaesthetic techniques including inhalational anaesthesia and for the high-risk patient.
- 8 Capillary blood glucose and ketone monitoring** should be immediately accessible in every location where patients are anaesthetised and blood glucose should be measured at least hourly in patients with treated diabetes.
- 9 Alarm limits** for all equipment should be set to patient-specific values before use. Audible alarms should be enabled during anaesthesia.

10 An anaesthetic record should be made with an accurate summary of information provided by all monitoring devices. We recommend automated electronic anaesthetic record systems and that these be integrated into the hospital's electronic health record system.

11 Additional equipment and monitoring that anaesthetists should have access to should include blood gas analysis and haemoglobin measurement and flexible bronchoscopy (for confirmation of tube placement in the airway).

*In hospitals employing Anaesthesia Associates (AAs) in the UK, this responsibility may be delegated to an AA, supervised by a consultant anaesthetist.

What other guideline statements are available on this topic?

The European Board of Anaesthesiology (2012) [1], the American Society of Anesthesiology (2020) [2] and the Australian and New Zealand College of Anaesthetists (2017) [3] have published guidelines on standards of clinical monitoring. The Association would like to take this opportunity to signpost anaesthetists from around the world to the World Health Organization-World Federation of Societies of Anaesthesiologists (WHO-WFSA) *International Standards for a Safe Practice of Anaesthesia* published in 2018 [4].

Why were these guidelines developed?

It was necessary to update the 2015 5th edition of this guideline [5] to include new guidance on monitoring following the introduction of new monitoring technology and the publication of new research into monitoring.

How and why does this statement differ from existing guidelines?

Capnography monitoring is essential at all times in patients with tracheal tubes, supraglottic airway devices and those who are sedated to a level unresponsive to verbal commands. A quantitative neuromuscular blockade monitor should be used whenever NMB drugs are administered. Processed EEG monitoring is recommended when using TIVA with neuromuscular blockade and may be helpful in targeting anaesthesia delivery in other circumstances. The importance of regular monitoring of blood glucose is emphasised. Anaesthetists should also have access to equipment for blood gas analysis, haemoglobin measurement and flexible bronchoscopy. A checklist for Clinical Directors is also included for the first time (Appendix 1).

Introduction

Human error is inevitable and there is widespread recognition that human factors and ergonomics are key to the safe delivery of healthcare in the UK [6]. There has been research into how human factors for anaesthetists are translated into clinical practice [7]. Safe and efficient task performance requires technical and non-technical skills. Monitoring will not prevent all adverse incidents or accidents in the peri-operative period. However, there is evidence that it reduces the risks of incidents and accidents by detecting the consequences of errors and by giving early warning that the condition of a patient is deteriorating [8].

Presence of the anaesthetist

The continuous presence of an appropriately trained and suitably experienced anaesthetist is the cornerstone of patient safety during anaesthesia. The anaesthetist should be with the patient at all times while the patient is anaesthetised or sedated, and at least until the WHO sign-out has been completed and the patient's care has been handed over to appropriately trained staff.

Deep sedation (where responsiveness is significantly obtunded) requires identical anaesthetic monitoring and, in such circumstances, the personnel present and monitoring should reflect this [9]. In many instances, sedation is given by other healthcare professionals and this is governed by local processes and by the guidance of their own professional organisations. The Academy of Medical Royal Colleges (AoMRC) provides guidance on safe sedation [10].

Trainees must be appropriately supervised at all times [9], and sometimes this means a consultant or suitably trained and experienced SAS doctor remaining with them providing direct supervision. Detailed recommendations regarding supervision are available [11].

Regional anaesthesia

Regional Anaesthesia UK (RA-UK) has issued guidance [12] that an anaesthetist may not need to remain present during surgery under peripheral regional anaesthesia in certain defined circumstances (e.g. brachial plexus block without sedation). This would include proceeding to perform regional anaesthesia on a second patient. The patient being left must be conscious and communicating effectively when responsibility is handed over to anyone other than an anaesthetist. In this situation, monitoring may be delegated to an appropriately trained healthcare worker. The anaesthetist should be immediately available for the first 15 min following block and thereafter be contactable and able to attend within 2 min. It follows that the staff members present in the operating theatre should be able to recognise

and manage any immediately life-threatening emergency in this time. If sedation or analgesia is required, then an anaesthetist must return to administer this and must be present until the patient is again conscious and communicating effectively.

Anaesthesia Associates

In hospitals employing Anaesthesia Associates (AA), formerly called Physicians Assistants (Anaesthesia), the responsibility to remain with the patient "may be delegated to AAs, supervised by a consultant anaesthetist in accordance with the scope of practice for AAs." [9]. The joint position of the Association and the Royal College of Anaesthetists has been set out in their joint statement [13] and this includes guidance on supervision of AAs at qualification. They should work within their own scope of practice, adhering to national guidance and local governance policies.

Emergencies

In exceptional circumstances, an anaesthetist may be called on to assist with or perform a life-saving procedure nearby and may briefly leave their primary patient. This is a matter for their individual judgement. If another anaesthetist (or where applicable, an AA) cannot be summoned, a dedicated anaesthetic assistant should remain present to monitor the patient being left [9]. The anaesthetist should return as soon as possible and immediately if required; they should ensure the person monitoring knows how to recall them. Departments should have a duty supernumerary anaesthetist whose role includes attendance at such emergencies.

Fatigue and vigilance

Fatigue degrades the ability to be vigilant. Organisations should put in place measures to ensure anaesthetists are protected from fatigue. This includes ensuring adequate breaks, providing rest facilities and observing the relevant working time legislation [14]. The Association has made available resources to help organisations and individuals towards this aim [15]. Fatigue is not restricted to night working; it also happens during the day. The duty supernumerary anaesthetist's role should include providing relief to solo colleagues during long cases, where fatigue and the waning of vigilance is a risk.

Cardiopulmonary bypass

The anaesthetist remains responsible for monitoring the patient during bypass. They should ensure they are able to monitor the patient to the same standard as at all other times during anaesthesia [9].

Anaesthetic record

An accurate summary of information provided by all monitoring devices should be kept. We recommend automated electronic anaesthetic record systems and these should preferably be in the form of anaesthesia information management systems integrated into the hospital's electronic health record system [16]. When manual anaesthetic charts are used, these should be structured to allow heart rate, blood pressure, S_pO_2 , $ETCO_2$ and (where used) pEEG to be recorded at least every 5 min and other values at least every 15 min. Additional values should be recorded if there are significant changes during these time intervals. It is recognised that contemporaneous records may be difficult to keep in emergency circumstances and, in this situation, gaps in the record should be completed once the clinical situation permits using the trend data stored in the monitoring devices.

Circumstances may dictate that handing over of responsibility for patient care under anaesthesia to another anaesthetist is necessary. If so, a detailed handover should be delivered to the incoming anaesthetist and the handover should be recorded in the anaesthetic record. A handover checklist is useful and one example of this is the 'ABCDE' aide-memoire suggested in the NAP5 report, D for drug delivery and E for effective team or environment [17]. When taking over care of a patient (including when returning after relief for a break), the incoming anaesthetist should satisfy themselves that all appropriate monitoring is in place with suitable alarm limits before accepting the handover of care.

Anaesthetic equipment

It is the responsibility of the anaesthetist to check all equipment before use and be familiar with it [18]. It is an organisational and individual responsibility that anaesthetists are adequately trained in the use of all the equipment they intend to use and that they have followed any specific equipment checks recommended by individual manufacturers. Provision, maintenance, calibration and renewal of equipment are the responsibilities of the institution in which anaesthesia is delivered. Organisations should involve anaesthetic departments in decision-making regarding monitoring equipment procurement and maintenance.

Oxygen supply

Integral hypoxic mixture protection and inspired oxygen measurement have for several years been a mandatory feature of anaesthesia workstations [19]. Any workstations that remain in service without hypoxic mixture protection or

with an external inspired oxygen analyser are therefore likely to be extremely old. We recommend any such machines are removed from service.

Monitoring the patient

During anaesthesia, the patient's physiological state and adequacy of anaesthesia need continual assessment. Monitoring devices supplement clinical observation in order to achieve this. Appropriate clinical observations include assessment of mucosal colour, pupil size, lacrimation, movements of the chest wall and/or the reservoir bag and absence of response to surgical stimuli. The anaesthetist may undertake palpation of the pulse, auscultation of breath sounds and, where appropriate, measurement of urine output and blood loss. A stethoscope should always be available.

Monitoring devices

The Association of Anaesthetists regards it as essential that minimum standards of monitoring are adhered to whenever a patient is anaesthetised, regardless of duration or location of anaesthesia. We consider the following to constitute minimum monitoring for anaesthesia:

In all cases:

- Pulse oximeter with plethysmograph
- NIBP
- ECG
- Temperature, before anaesthesia and every 30 min until the end of surgery [20]

During general anaesthesia, add:

- Inspired and expired oxygen
- Waveform capnography

Depending on technique, add:

- Inspired nitrous oxide concentration, if used
- Inspired and end-tidal inhalational anaesthetic drug concentration, if used
- Airway pressure, tidal volume and respiratory rate during mechanical ventilation
- Quantitative neuromuscular monitoring, throughout all phases of anaesthesia, whenever NMB drugs are used
- Processed EEG, when administering TIVA with neuromuscular blockade
- Capillary blood glucose monitoring (this should be immediately accessible)
- During procedural sedation whenever there is loss of response to verbal contact, add waveform capnography.

Infusion devices

When any component of anaesthesia is administered by infusion, the infusion device should be checked before use. Pumps for target-controlled infusions and fixed-rate infusions should have audible alarms enabled by default. Alarms should include: high-pressure; cessation of infusion; empty syringe; disconnection from the mains electricity supply; and low battery. Some pumps also have a low-pressure alarm which may permit some disconnections to be detected. There should be a visual display to indicate that the infusion is in progress [21]. Infusion devices are subject to medical device regulations and a device should only be used for the purpose (drug) intended. Particular caution should be exercised for using infusion pumps to deliver unlicensed medications.

It is recommended that the intravenous cannula should be visible throughout the procedure, when this is practical. When using TIVA with neuromuscular blockade, a quantitative neuromuscular blockade monitor and a pEEG monitor should be used.

Alarms

Anaesthetists should ensure that all alarms are set to appropriate values and enabled. The existing alarm settings may be inappropriate. It is recommended that anaesthetic departments agree consensus-based alarm limits for their monitors and ask their medical engineering department or equivalent to set these up. These alarm defaults should be standardised within any department. Increasingly, devices are available with 'smart alarms', using algorithms to assess alarm priority and communicate clinical importance more efficiently; wherever this technology is available, organisations should consider adopting it.

Intra-operative hypotension is associated with adverse outcomes related to both severity and duration. Non-invasive blood pressure should be measured at least every 5 min, but hypotension occurring in-between 5 min recording intervals may be associated with adverse outcomes. The retrospective and observational nature of most evidence precludes further recommendations. Particular care should be taken that NIBP monitors do not continue to display readings for > 5 min to reduce the risk of displaying an older reading.

Cuff pressures in airway devices

The cuff inflation pressure of a cuffed tracheal tube or cuffed supraglottic airway device should be monitored with a suitable manometer. Manufacturers' instructions for use of the airway should be consulted and the pressure should not

exceed any recommended maximum, which can be associated with increased patient morbidity. This is especially important if nitrous oxide is used as this can diffuse into the cuff and increase pressure.

When using supraglottic airway devices where manufacturers do not specify or recommend a maximum cuff pressure, there may still be benefit in avoiding high pressure inflation (> 60 cmH₂O), as this is associated with reduced morbidity and improved device performance [22]. Tracheal tubes should be inflated with the minimum amount of air necessary to prevent a leak. The differing cuff characteristics of tracheal tubes available in the operating theatre, the wide range of durations of surgical operations and the lack of systematically derived evidence means there is no generalisable advice on maximum cuff pressure in tracheal tubes used in anaesthesia.

Duration of minimum monitoring

Monitoring should continue until the patient is discharged from PACU, including during transfer to the PACU [23].

During induction of anaesthesia in children and in unco-operative adults, it may not be feasible to attach all monitoring before induction. In these circumstances, monitoring should be attached as soon as possible and the reason for delay recorded.

Monitoring the airway

Hearing, sight and touch may be applied to airway monitoring. A partially obstructed airway will generally produce a noise unless obstruction is complete. A malpositioned artificial airway may produce a noise due to airway leak, obstruction, stridor or wheeze. However, despite the value of clinical skills in highlighting problems, confirmation of the nature of such a problem is often facilitated by anaesthetic monitoring devices.

Pressure and volume monitoring

Airway pressure monitoring should be used during controlled ventilation and is also recommended during spontaneous ventilation. During controlled ventilation, monitoring peak, plateau, mean and end expiratory airway pressure, ideally as a displayed waveform, provides breath-by-breath information about chest-lung mechanics. During spontaneous ventilation, airway pressure monitoring may detect airway obstruction, excessive tidal volumes (sub-atmospheric pressure) and accidental closure of the adjustable pressure relief valve. Audible alarms should be on and set to the specific needs of the individual patient and mode of ventilation. Tidal volume, respiratory rate and

minute volume are also key components of routine airway monitoring.

Spirometry

Combining pressure, flow and volume measurements enables breath-by-breath spirometry to be displaced on many anaesthetic machines. Although not mandatory, display and skilled interpretation of spirometry loops enables rapid detection of changes in lung mechanics.

Capnography

Capnography monitoring is essential at all times in patients with tracheal tubes, supraglottic airway devices and those who are sedated and do not respond verbally. Capnography is a vital monitor of airway patency and of alveolar ventilation. The importance and breadth of its role has only become apparent recently [24–26]. It should be used for monitoring the airway during anaesthesia, wherever that takes place [26–29].

During tracheal intubation

Waveform capnography is the gold standard and should be used routinely for detecting correct tracheal intubation [26]. It has both high sensitivity and specificity.

Alternative methods of detecting correct intubation such as palpation and auscultation lack sensitivity and specificity. Ultrasound may be used to confirm correct tracheal intubation but requires training, skill and equipment that are not always immediately available. Where there is significant clinical difficulty about confirming correct tracheal intubation (e.g. profound bronchospasm), skilled use of a flexible bronchoscope is of value.

Detecting accidental oesophageal intubation

Capnography is also the gold standard for correctly detecting accidental oesophageal intubation, with both high sensitivity and specificity. Failure to detect oesophageal intubation because of failure to use or correctly interpret capnography has been a Never Event in the UK [30], though this is currently withdrawn while under review [31]. A flat capnogram after attempted tracheal intubation should be considered to indicate oesophageal intubation until this has been excluded [26, 32–34]. This includes when the patient is in cardiac arrest; if the trachea is intubated even during cardiac arrest an attenuated capnogram trace will be present [35]. An educational video on this topic is highlighted [36].

Uninterrupted capnography monitoring should occur during induction of anaesthesia, airway insertion, maintenance of anaesthesia, during any transfers and

during emergence from anaesthesia [24, 26, 29]. This includes until a tracheal tube or supraglottic airway is removed [23].

Capnography has numerous other monitoring roles including detecting bronchospasm or other lung pathology, rebreathing of carbon dioxide and signalling alterations in metabolic status such as malignant hyperthermia.

During sedation, capnography should be used whenever verbal contact with the patient is lost. It is also advised for lighter levels of sedation to aid monitoring of airway patency, respiratory rate and pattern [25, 37].

The Working Party makes the above recommendations regarding use of capnography for all patients, of all ages and in all locations. The safe use and interpretation of waveform capnography in very small babies (e.g. < 1 kg) requires specialist expertise [32, 38].

Clinicians who manage the airway independently should be skilled at recognition of interpretation of normal and abnormal capnogram patterns. Those monitoring patients with capnography during emergence from anaesthesia or sedation should be trained in the recognition of safe and unsafe capnography patterns; tools are available to facilitate this [39].

Monitoring of neuromuscular blockade

Residual neuromuscular blockade, defined as a train-of-four (ToF) ratio < 0.9, remains an important issue, with a reported incidence ranging from 4% to 64% [40]. Harmful consequences of inadequate recovery include: generalised muscle weakness and delayed recovery [41]; reduced chemoreceptor mediated responsiveness to hypoxia [42]; risk of aspiration; postoperative pulmonary complications [43]; and accidental awareness during general anaesthesia (AAGA) [17].

Clinical tests of recovery (sustained head-lift, hand grip, tongue depressor tests) are inadequate, with sensitivities of 10–30% and positive predictive values < 50% at best. Clinical signs such as spontaneous respiration, perceived adequacy of tidal breaths, coughing on a tracheal tube and extremity movements to command, similarly do not exclude residual blockade. Qualitative peripheral nerve stimulator assessment is unable to guarantee adequacy of neuromuscular blockade recovery [44]. Absence of tactile or visible ToF fade using a peripheral nerve stimulator only indicates ToF ratio recovery to 0.4 or greater. The 'monitoring gap' between 0.4 and unity can only be assessed using quantitative monitoring. This is especially important given the variability and often prolonged response to intermediate duration NMB drugs. One such

study demonstrated that 37% of patients entering recovery 2 h or more after a single 2 x ED₉₅ dose, had ToF ratios < 0.9 [45].

Quantitative neuromuscular monitoring is, therefore, essential and should be used when administering NMB drugs [46]. This includes the use of succinylcholine and mivacurium. A Danish registry showed a higher incidence of premature awakening, residual paralysis and re-intubation need for unmonitored patients with butyrylcholinesterase deficiency [47].

Every operating theatre or location where NMB drugs are used should be equipped with a quantitative neuromuscular monitoring device. The monitor should be applied along with other essential monitoring, activated after induction of general anaesthesia but before neuromuscular blockade, and used throughout all phases of anaesthesia. Adequacy of recovery (ToF ratio > 0.9) should be demonstrated and documented before patient awakening and extubation. The ulnar nerve is the most useful site for neuromuscular monitoring. However, if thumb movement is impeded, for example, when the hand is inaccessible during surgery, readings may be unreliable especially when acceleromyography devices are used. Alternative options include the use of electromyography devices [46], a compressomyography device such as the TOF-Cuff (Gwenagen Ltd, Leeds, UK) or use of alternative sites such as the facial or tibial nerve. If facial nerve monitoring is used, the risk of residual paralysis is five times greater and it is best to revert to ulnar nerve stimulation at the end of surgery [48].

Inhalational anaesthetic drug monitoring

When general anaesthesia is maintained by means of an inhaled anaesthetic drug, measurement of the end-tidal anaesthetic concentration (ETAC) provides confirmation that the anaesthetic drug is being delivered to the patient and can provide an approximate indication of the drug concentration in the patient's blood and brain.

Maintaining ETAC > 0.7 age-adjusted MAC during maintenance of general anaesthesia with an inhalational anaesthetic drug appears to be an effective means of reducing the risk of AAGA [49, 50].

Therefore, the Working Party recommends that ETAC should be monitored whenever an inhaled anaesthetic drug is used for general anaesthesia. During the maintenance phase of anaesthesia, an audible alarm should be enabled to indicate a low ETAC (e.g. < 0.7 age-adjusted MAC) in order to reduce the risk of AAGA [50]. It is recommended that monitors have the facility for an age-adjusted MAC

alarm to be set directly rather than only permitting an anaesthetic concentration alarm to be set because the latter requires the anaesthetist to calculate the age-adjusted MAC for each patient.

Processed EEG monitoring

Processed electroencephalogram (pEEG) 'depth of anaesthesia' monitoring provides an indication of the effect of the most commonly used general anaesthetic drugs (including propofol and the inhalational anaesthetic drugs) on the electrical activity of the frontal cerebral cortex. It may aid the anaesthetist in adjusting the dose of anaesthetic drug being given to an individual patient and reduce the incidence of adverse effects resulting from an inadequate or excessive anaesthetic dose. Processed EEG monitoring may reduce the risk of AAGA, improve early recovery times and reduce the incidence of postoperative delirium and postoperative cognitive dysfunction [17, 51, 52]. The 5th National Audit Project on AAGA (NAP5) [17] concluded the vast majority of definite or probable cases occurred during anaesthetics which involved the administration of a NMB drug so that the problem was that of unintended awareness during neuromuscular blockade.

When general anaesthesia is maintained using TIVA, monitoring is not yet widely available to confirm whether the anaesthetic drug is being delivered to the patient as intended. Processed EEG monitoring should, therefore, be used when TIVA is administered together with neuromuscular blockade and should be considered when TIVA is used alone. Monitoring should start before induction and continue at least until full recovery from the effects of the NMB drug has been confirmed.

It is important to note that the studies of ETAC monitoring have only looked at intra-operative awareness and not included episodes that occur before the start of or after the end of surgery. In NAP5, almost two-thirds of cases of AAGA occurred either before the start or after the end of surgery and it was concluded that most of these cases could not have been prevented by ETAC monitoring [17]. Therefore, there may also be a role for pEEG monitoring in the reduction of AAGA in patients receiving inhalational general anaesthesia. Benefits of pEEG monitoring resulting from a reduced risk of administering excessive anaesthesia are likely to apply irrespective of whether an NMB drug has been given.

Anaesthetists should not rely solely on index values displayed by pEEG monitors. Rather, they should develop a basic understanding of EEG waveforms and the interpretation of information from power spectral analysis,

density spectral array ('spectrograms') and relative band powers.

Cardiovascular monitors

The use of additional cardiovascular monitoring during anaesthesia should be considered, for instance due to cardiovascular comorbidity, frailty, the emergency or specific nature of the surgery; several methods exist. For example, clinicians may consider using cardiac output measurement directly to titrate a vaso-active infusion and optimisation of stroke volume may be considered.) [53–57]

An increasing number of cardiac output monitors of a 'less invasive' and 'non-calibrated' or 'auto-calibrated' nature are available. They are frequently inaccurate at the extremes of measurement and at the limits of physiology, and right heart catheterisation and thermodilution remains the most accurate and best validated technique. Cardiac output monitoring can be technically demanding and specific to the device so anaesthetists should ensure they are trained and competent in the use of the specific device.

There is a paucity of data around cardiac output monitoring in specialist populations, for example, paediatrics and obstetrics. Because of its ability to identify aetiology and structure, echocardiography is recommended as the initial diagnostic study in the setting of shock.

Monitoring during transfer within the hospital

The standard of care and monitoring required during transfer of patients who are anaesthetised or sedated is equivalent to that required in the operating theatre, and personnel with adequate knowledge and experience should accompany the patient [58]. This includes patients who are being transferred from the operating theatre to the PACU. A tested and functioning oxygen supply sufficient to last the duration of the transfer is essential for all patients.

Portable oxygen cylinders

Portable oxygen cylinders may not include a clear visual indicator of oxygen flow. When administering oxygen from a portable cylinder, the anaesthetist should confirm it is sufficiently full, that all valves are open in the correct order [59] and there is a sustained flow at the outlet by feel and sound. As technologies to monitor flow become available, these should be considered for implementation [60].

Capillary blood glucose monitoring

In a national audit, 18.4% of inpatients with diabetes had been admitted for non-medical reasons [61]. Capillary blood glucose $< 4 \text{ mmol.l}^{-1}$ [62, 63] and $> 10 \text{ mmol.l}^{-1}$ [64,

65, 66] are associated with an increased risk of infective and non-infective postoperative complications. In 2015, the Association recommended a target peri-operative capillary blood glucose range of 6–10 mmol.l^{-1} (an upper limit of 12 mmol.l^{-1} may be tolerated), checked before induction of anaesthesia and monitored regularly during the procedure (at least hourly in patients with diabetes, or more frequently if results are outside the target range). The lower limit of 6 mmol.l^{-1} is to act as a buffer to ensure action is taken to prevent hypoglycaemia in the surgical patient, especially if the patient is on glucose lowering medication, that is, insulins (either subcutaneously or via an insulin infusion), sulphonylureas and meglitinides [67].

Anaesthetists should have immediate access to capillary blood glucose monitoring equipment. Patients with diabetes mellitus controlled by medication should have their blood glucose monitored intra-operatively at least hourly.

Capillary blood ketone monitoring

Diabetic ketoacidosis is a dangerous condition, and hospital-acquired diabetic ketoacidosis is the third most common cause of diabetic ketoacidosis after infection and non-compliance [68]. As well as occurring in surgical patients with type-1 diabetes who have persistent hyperglycaemia [69], it may also occur in surgical patients with type-2 diabetes treated with sodium-glucose linked transporter inhibitors [70]

Anaesthetists should have ready access to capillary blood ketone monitoring equipment.

Anaesthesia in locations outside the operating theatre

When anaesthetists are required to administer general or regional anaesthesia and/or sedation in locations outside the operating theatre, the same minimum essential standards of monitoring already outlined in this document should apply [9, 71–73].

Monitoring in the magnetic resonance imaging unit

The Association has published detailed guidance about anaesthesia in magnetic resonance imaging (MRI) units [74]. It is recognised that the MRI unit presents unique challenges for the anaesthetist. The minimum standard of monitoring in both the MRI induction area and scanner should, however, be the same as that provided within the operating theatre. Magnetic resonance imaging-safe or conditional equipment (e.g. fiberoptic pulse oximeters, MRI-safe ECG electrodes and NIBP monitoring) may be different to that

used elsewhere in the hospital and anaesthetists should receive specific training with this equipment before use. In addition, MRI-safe anaesthetic machines and monitors are often more basic with poor access to alarms, so this area should be considered to be high-risk. Therefore, the MRI unit set-up should allow remote monitoring in the control unit while scanning is taking place.

Monitoring during sedation

There is a very fine line between sedation and anaesthesia, and the former can easily lead to the latter.

The practice of procedural sedation is the administration of one or more pharmacological drugs to facilitate a diagnostic or therapeutic procedure while targeting a state during which airway patency, spontaneous respiration, protective airway reflexes and haemodynamic stability are preserved, while alleviating anxiety and pain [75].

The same standards of monitoring should be applied for patients receiving sedation as for general anaesthesia – namely NIBP, pulse oximetry and continuous ECG. Capnography should be used in patients whenever there is loss or likelihood of loss of normal response to verbal contact [76–78]. The provider of the sedation should remain present during the episode of care, regardless of the depth of sedation.

Regional anaesthesia

Whenever regional anaesthesia is being performed, the same minimum standards of monitoring should be applied as if for general anaesthesia. Capnography should be used in patients whenever there is loss or likelihood of loss of normal response to verbal contact.

When siting a regional anaesthetic for analgesic purposes where a patient will not remain in an operating theatre or critical care environment (e.g. for rib or proximal femur fracture), a suitable period of minimum monitoring should be maintained to monitor for adverse effects from the delivery of the bolus of local anaesthetic. Local anaesthetic systemic toxicity most frequently presents immediately after injection of local anaesthetic but plasma levels of local anaesthetic can peak between 30 and 90 min after the initial injection [79, 80]. A minimum period of monitoring of 30 min should be considered under these circumstances [81, 82].

RA-UK has issued guidance [12] that an anaesthetist may not need to be present during surgery under peripheral regional anaesthesia in certain defined circumstances, for example, brachial plexus block (neuraxial blocks and awake surgery in the 'beach-chair' position are

excluded from this advice). Monitoring the patient may be delegated to an appropriately trained healthcare worker. The anaesthetist should be immediately available for the first 15 min following block and thereafter be contactable and able to attend within 2 min. It follows that the staff members present in the operating theatre should be able to recognise and manage any immediately life-threatening emergency in this time.

Acknowledgements

AK or his institution have received educational grant funding honoraria or travel expenses in the last 3 years from Fisher and Paykel, Massimo, Nordic Pharma and Pharmacosmos. AK is the Editor-in-Chief of *Anaesthesia*. AP has received honoraria from GE Healthcare and Sintetica Ltd, and consults for B Braun Medical Ltd. TM, TS and PY are elected Board members of the Association of Anaesthetists. No other competing interests declared.

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Appendix 1 Checklist for clinical directors

- 1** All procurement decisions should be compliant with current environmental and sustainability advice.
- 2** Sufficient flexibility should be built into the staffing of clinical areas in daytime and out of hours to provide for unpredictable requirements.
- 3** Sidestream or in-line capnography should be procured for all areas where airway interventions may occur (all theatres, anaesthetic rooms, recovery bays, emergency departments, resuscitation carts, intensive care bed spaces, transfer equipment).
- 4** Every operating theatre should have a dedicated quantitative neuromuscular monitor.
- 5** Sufficient processed EEG monitors should be procured for departmental needs.
- 6** Blood gas analysis equipment, capillary glucose and ketone measuring devices should be procured to ensure immediate accessibility.
- 7** Flexible bronchoscopes, available for immediate confirmation of tracheal tube placement should be procured.
- 8** Anaesthetic charts should be designed to facilitate recommended recording frequency, including SpO₂ every 5 min; we recommend that automated electronic recording systems are used.
- 9** Cuff pressure manometers should be procured so that inflation of airway device cuffs is compliant with manufacturers' instructions for use.