PATIENT MONITORING

# Monitoring small animal patients in the intensive care unit

Karen Humm, Lindsay Kellett-Gregory

**All patients in an intensive care unit (ICU) have instability in at least one of the major body systems (cardiovascular, neurological and respiratory systems) or the potential for this to develop. If these systems are not functioning appropriately, death can result. The aim of intensive care is therefore to prevent this by monitoring for, recognising and treating any instability. This article focuses on when intensive care is required and how to monitor a patient in the ICU effectively.**

## Which patients benefit from intensive care?

Intensive care is clearly not required by the majority of hospitalised veterinary patients. Those that would benefit have a wide variety of disease processes and clinical signs including:

- Trauma-induced pathology;
- Seizures;
- Dyspnoea;
- Medical diseases (eg, diabetic ketoacidosis and severe pancreatitis);
- Postsurgical status (eg, after a thoracotomy);
- Marked anaemia;
- Cardiac arrhythmias.

Given the nature of the diseases requiring intensive care, owners of animals in the intensive care unit (ICU) require careful counselling. Disease severity, likely financial and emotional costs for the owner, and the dynamic nature of ICU patients with the potential for rapid changes in condition and variable recovery times should all be discussed. Many vets also choose to discuss resuscitation status with owners of a patient in the ICU.

## Effective monitoring

Monitoring in the ICU focuses on the major body systems - the cardiovascular, neurological and respiratory systems (see the triage article on pp 6-11 in this supplement). This allows the clinician to determine whether a patient is stable, improving or deteriorating. Appropriate monitoring - in terms of what is monitored and how frequently - is customised and concentrates on the particular issues of the individual patient and the complications that could develop. For example, a cat admitted to the ICU with pulmonary oedema secondary to congestive heart failure that has just been administered furosemide, may have its respiratory rate assessed every 20 minutes to gauge treatment efficacy, whereas a dog with primary immune-mediated thrombocytopenia and no respiratory tract pathology may only require a respiratory rate check every 12 hours to confirm that there has been no change in status.

Therefore, for effective monitoring, each ICU patient needs to be assessed at least once a day. The clinician should be aware of:

- The patient's problem list;
- Any previous or current major body system instability;
- The potential for any deterioration or improvement in the patient's disease process(es);
- Potential disease-related complications that could develop;
- Possible adverse reactions to therapies;
- How improvement, deterioration, complications and adverse reactions could be recognised.

With this knowledge, an appropriate monitoring day sheet can be created. As monitoring will likely be carried out by several members of staff, it is very useful to have 'notify if' values, so that the primary clinician with ultimate responsibility for the patient can be contacted if findings emerge that are of concern - that is, indications of primary disease deterioration, complications or an adverse reaction.

Veterinary ICUs should be constantly staffed to deal with the high monitoring and care demands of their patients. This allows all patients to be under constant surveillance without their monitoring sheet explicitly stating this. This 24-hour care means that changes in patient status (eg, the development of dyspnoea or seizures) will be noted, investigated and treated rapidly, with a new monitoring plan and sheet developed for that animal.

Karen Humm, Lindsay Kellett-Gregory,
Small Animal Medicine and Surgery Group,
Royal Veterinary College, Hawkshead Lane,
North Mymms, Hatfield, Hertfordshire
AL9 7TA, UK
e-mail: khumm@rvc.ac.uk

## Pain

Although monitoring and attempting to maintain stability of the major body systems is the key component of critical care, minimising pain is one of the most important responsibilities of veterinary professionals. To try to do this, pain should ideally be measured effectively and accurately, but this is difficult to do. The World Small Animal Veterinary Association states that pain assessment should be part of every patient assessment, but recognises that it is a uniquely individual experience (Mathews and others 2014). Elevated heart rate, respiratory rate and blood pressure can all be associated with pain but many other factors can also cause these changes, particularly in patients in the ICU with serious underlying disease processes.

Pain can be subjectively assessed by ICU staff looking at patient body position, facial expression and demeanour, with previous knowledge of the patient thought to aid the recognition of pain. However, it is known that there can be marked variability between assessors using this method for pain assessment, so to try to counteract this, 'pain-scoring' tools have been designed. The Glasgow composite measure pain scale short form (CMPS-SF) is validated for the assessment of acute pain in dogs (Box 1) and a feline version (CMPS-F) has now been developed and validated (Box 2). Many veterinary ICUs have introduced these scales to improve the recognition of pain and, therefore, improve treatment.

Response to appropriate analgesic treatment is the gold standard for assessing the presence and degree of pain an animal is experiencing (Mathews and others 2014). Therefore, if there is doubt either as to whether the ICU patient is in pain and requires analgesia, or whether sufficient analgesia is being provided, additional analgesia (via either increased doses or administration of a different or additional drug) can be provided and the patient reassessed. Opioid administration can lead to difficulties in assessing pain in animals, with dysphoria sometimes being misinterpreted as pain-induced behaviour. In these situations, trialling a lower dose of an

## Box 1: Glasgow composite measure pain scale short-form for the assessment of acute pain in dogs

Choose the appropriate score for each section and add these together to give the total score. A total score of 6 or above suggests additional analgesia is required. In cases of spinal, pelvic or multiple limb fractures, or where assistance is required to aid locomotion, do not carry out section B and proceed to section C. In this situation, a total score of 5 or above suggests additional analgesia is required.

**Section A**
Observe the dog in its kennel. Is the dog:
(i)
- Quiet? - score 0;
- Crying or whimpering? - score 1;
- Groaning? - score 2;
- Screaming? - score 3.

(ii)
- Ignoring any wound or painful area? - score 0;
- Looking at a wound or painful area? - score 1;
- Licking a wound or painful area? - score 2;
- Rubbing a wound or painful area? - score 3;
- Chewing a wound or painful area - score 4.

**Section B**
Put a lead on dog and lead it out of the kennel. When the dog rises/walks, is it:
(iii)
- Normal? - score 0;
- Lame? - score 1;
- Slow or reluctant? - score 2;
- Stiff? - score 3;
- Refusing to move? - score 4.

**Section C**
If the dog has a wound or painful area, including the abdomen, apply gentle pressure 5 cm round the site. Does the patient:
(iv)
- Do nothing? - score 0;
- Look round? - score 1;
- Flinch? - score 2;
- Growl or guard the area? - score 3;
- Snap? - score 4;
- Cry? - score 5.

**Section D**
Overall, is the dog:
(v)
- Happy and content or happy and bouncy? - score 0;
- Quiet? - score 1;
- Indifferent or non-responsive to its surroundings? - score 2;
- Nervous or anxious or fearful? - score 3;
- Depressed or non-responsive to stimulation? - score 4.

(vi)
- Comfortable? - score 0;
- Unsettled? - score 1;
- Restless? - score 2;
- Hunched or tense? - score 3;
- Rigid? - score 4.

Total score (i + ii + iii + iv + v + vi) = /24

## Box 2: Glasgow composite measure pain scale - feline, for the assessment of acute pain in cats

Choose the most appropriate expression from each section and add the scores together to calculate the pain score for the cat; if more than one expression applies, choose the higher score. A total score of 4 or above suggests additional analgesia is required.

**Look at the cat in its cage. Is it:**
(i)
- Silent/purring/meowing? - score 0;
- Crying/growling/groaning? - score 1.

(ii)
- Relaxed? - score 0;
- Licking its lips? - score 1;
- Restless/cowering at back of its cage? - score 2;
- Tense/crouched? - score 3;
- Rigid/hunched? - score 4.

(iii)
- Ignoring any wound or painful area - score 0;
- Paying attention to a wound - score 1.

**Approach the cage, call the cat by its name and stroke its back from head to tail.**
(iv)
- Does it respond to stroking? - score 0;
- Is it unresponsive? - score 1;
- Is it aggressive? - score 2.

**If it has a wound or painful area, apply gentle pressure 5 cm around the site; in the absence of any painful area, apply similar pressure around the hindleg above the wound. Does the patient:**
(v)
- Do nothing? - score 0;
- Swish its tail/flatten its ears? - score 1;
- Cry/hiss? - score 2;
- Growl? - score 3;
- Bite/lash out? - score 4.

**General impression - is the cat:**
(vi)
- Happy and content? - score 0;
- Disinterested/quiet? - score 1;
- Anxious/fearful? - score 2;
- Dull? - score 3;
- Depressed/grumpy? - score 4.

Pain score (i + ii + iii + iv + v + vi) = /16

opioid is acceptable if the patient is closely monitored and additional analgesia provided immediately if required.

## Basic physical examination

ICU patients should have a thorough physical examination at least once a day. This is to assess progression of the primary disease process and recognise any complications. Common complications include:

- Corneal ulceration;
- Oedema formation;
- Faecal and urinary scalding;
- Wound inflammation;
- Thrombophlebitis;
- Hospital-acquired infections, including aspiration pneumonia and urinary tract infections (see the nursing article on pp 25-29 in this supplement for further details).

Each disease process will also have particular complications to consider, such as ventricular arrhythmias in dogs with postoperative gastric dilation and volvulus, and pulmonary thromboembolism in immune-mediated haemolytic anaemia patients.

Assessment of the patient's temperature, pulse rate and respiration rate is generally performed more than once a day. Frequent measurements of these basic respiratory parameters are required in unstable patients. Further monitoring (eg, of the cardiovascular system), although desirable, may not be possible due to the risk of deterioration with patient handling. If the patient is more stable, regular lung field auscultation alongside respiratory rate measurement is useful, particularly if there is a risk of pneumothorax, pleural fluid, pneumonia or pulmonary oedema.

## Body temperature

Measurement of body temperature allows recognition of the development of a pyrexia, or monitoring of a known pyrexia. It generally does not need to be performed more than twice daily, as most patients resent the use of rectal thermometers. Aural thermometers can be used to monitor individual patient temperature trends but they typically underestimate core body temperature. More frequent temperature checks may be required in hypothermic patients (those recovering from general anaesthesia or paediatric or small-breed patients) or in patients that have, or are at risk of, hyperthermia (such as dogs with upper respiratory tract obstruction, for example, brachycephalic breeds, patients with laryngeal paralysis). In these patients, a pragmatic approach to the frequency of temperature measurement is required.

**Table 1: Causes of electrolyte and glucose disturbances in patients in intensive care units**

| Condition | Cause* |
|---|---|
| Hypernatraemia | **Vomiting and/or diarrhoea**<br>Burns<br>Diuretic use<br>Renal disease<br>Diabetes insipidus (central or renal)<br>Lack of access to water<br>Primary hypodipsia<br>Administration of high sodium fluids (eg, hypertonic saline, total parenteral nutrition)<br>Hyperaldosteronism (Conn's syndrome) |
| Hyponatraemia | **Vomiting and/or diarrhoea**<br>**Abdominal/pleural fluid**<br>Burns<br>Hypoadrenocorticism (Addison's disease)<br>Administration of low sodium fluids (eg, 5 per cent dextrose, 0.18 per cent sodium chloride)<br>**Congestive heart disease**<br>Liver failure<br>Renal disease<br>Syndrome of inappropriate antidiuretic hormone secretion |
| Hyperkalaemia | **Anuric/oliguric acute kidney injury**<br>**Urethral obstruction**<br>Uroabdomen<br>Hypoadrenocorticism (Addison's disease)<br>Repeated drainage of chylothorax<br>Intestinal parasites<br>Tissue necrosis |
| Hypokalaemia | **Low potassium-containing fluid administration (eg, Hartmann's solution, 0.9 per cent sodium chloride)**<br>**Anorexia**<br>**Chronic kidney disease (CKD)**<br>**Vomiting and/or diarrhoea**<br>Hyperaldosteronism (Conn's syndrome)<br>Diuretic use<br>Insulin administration |
| Hypercalcaemia | **Neoplasia (lymphoma, anal gland adenocarcinoma)**<br>Vitamin D intoxication<br>**CKD**<br>Acute kidney injury<br>**Idiopathic (cats)**<br>Granulomatous disease (including angiostrongylosis)<br>Hypoadrenocorticism (Addison's disease)<br>Hyperthyroidism |
| Hypocalcaemia | **Critical illness**<br>**Pancreatitis**<br>Hypoparathyroidism<br>**CKD**<br>Puerperal tetany<br>**Hypoproteinaemia can result in a low total calcium level** |
| Hypoglycaemia | **Sepsis**<br>Hypoadrenocorticism (Addison's disease)<br>**Neonatal patient with immature hepatic function**<br>Xylitol toxicity<br>**Insulin overdose**<br>Insulinoma<br>Hepatic failure |

* Common causes are given in bold

## Heart and pulse rates

The assessment of heart rate and pulse rate, as well as pulse quality, provides a useful global indicator of the patient's cardiovascular system. Frequent monitoring (at least hourly) of these parameters is required in any patient with cardiovascular instability, especially if specific therapy is being administered, such as a fluid bolus to a hypovolaemic patient. It is important to recognise that, although both dogs and cats in shock can be tachycardic, cats can also develop relative bradycardia (eg, a heart rate of 140 to 160 beats per minute [bpm]) with poor-quality pulses.

Assessing pulse rate and quality together allows differentiation of differing causes of tachycardia, such as pain and excitement (in which the pulse quality would be expected to be good) from shock and anaemia (in which the pulse quality would be expected to be hyperdynamic or poor). If pulse irregularity (other than sinus arrhythmia in a dog) or pulse deficits (heart beats without a concurrent palpable pulse) are noted, assessment of an electrocardiogram (ECG) is recommended (see below).

## Respiratory rate

Respiratory rate monitoring is a vital part of the management of any patient with a compromised respiratory system. It should be monitored alongside a subjective assessment of respiratory effort (noting whether this is inspiratory, expiratory or both), upper respiratory tract noise, orthopnoea, paradoxical abdominal movement and cyanosis. These assessments can all be made from a distance, so the patient need not be handled, which is of great benefit as dyspnoeic patients (particularly cats) can deteriorate rapidly due to increased oxygen demand if stressed. It also allows the patient to be monitored in an oxygen cage maintaining a high fractional-inspired oxygen concentration.

## Neurological assessment

Patients that have neurological abnormalities, including seizures, traumatic brain injury and inflammatory CNS disease, require close monitoring as they can rapidly deteriorate. Monitoring may be observation from a distance only, but in obtunded, stuporous or comatose patients, regular assessment of responsiveness, pupil size and cranial nerve reflexes are important. The modified Glasgow coma scale can be a useful tool for monitoring patient progression although it was originally designed for initial patient assessment (Platt 2005).

## Hydration

Hydration status is generally monitored once or twice a day as it does not change rapidly. Assessment via physical examination findings such as skin tenting and mucous membrane tackiness is quite subjective. However, bodyweight can be used to assess dehydration if a recent weight is known for the patient when it was healthy. In all cases, weight can be used to monitor whether a patient is being effectively rehydrated when a gain in bodyweight would be expected.

In patients at risk of volume overload (eg, anuric/oliguric acute kidney injury patients), regular weight checks (two or three times a day) can allow recognition of both fluid retention and overload when the bodyweight will increase. This is particularly useful if a urethral catheter cannot be placed and urine output cannot be accurately calculated.

# Packed cell volume and total protein

Monitoring a patient's packed cell volume (PCV) only requires simple equipment, but can be very informative, generally in patients with anaemia or those at risk of blood loss, for example, surgical patients or those with a coagulopathy. In conjunction with total protein (TP) measurement, PCV can be used to monitor hydration status; however, given the frequency of hypoproteinaemia and anaemia in ICU patients, interpretation can be difficult.

Unless rapid blood loss is suspected, monitoring PCV and TP once a day is generally sufficient. This allows the clinician to assess whether hydration is appropriate and whether the patient requires a blood product transfusion.

**Table 2: Normal arterial blood gas values for dogs and cats***

| Parameter | Dogs | Cats |
|---|---|---|
| pH | 7.39 ± 0.03 | 7.39 ± 0.08 |
| $PaCO_2$ (mmHg) | 37 ± 3 | 31 ± 6 |
| $PaO_2$ (mmHg) | 102 ± 7 | 107 ± 12 |
| $HCO_3^-$ (mmol/l) | 21 ± 2 | 18 ± 4 |
| Base excess (mmol/l) | -2 ± 2 | 18 ± 4 |

* Silverstein and Hopper (2015)
$PaCO_2$ Arterial partial pressure of carbon dioxide, $PaO_2$ Arterial partial pressure of oxygen, $HCO_3^-$ Bicarbonate

**Table 3: Common acid-base disorders seen in small animal patients and the underlying causes**

| Acid-base disturbance | pH | Primary disorder | Compensation | Differential diagnosis |
|---|---|---|---|---|
| Respiratory acidosis | Decreased | Increased $PCO_2$ | Increased $HCO_3^-$ or base excess | Hypoventilation (upper airway obstruction, anaesthetic drugs, neuromuscular disease, etc) |
| Respiratory alkalosis | Increased | Decreased $PCO_2$ | Decreased $HCO_3^-$ or base excess | Hyperventilation (fear, pain, anxiety, hypoxaemia, anaemia) |
| Metabolic acidosis | Decreased | Decreased $HCO_3^-$ or base excess | Decreased $PCO_2$ | Lactic acidosis, ketoacidosis, uraemic acidosis, toxins (ethylene glycol, metaldehyde, salicylates, etc) |
| Metabolic alkalosis | Increased | Increased $HCO_3^-$ or base excess | Increased $PCO_2$ | Vomiting, diuretic therapy |

$PCO_2$ Partial pressure of carbon dioxide in the blood, $HCO_3^-$ Bicarbonate

## Blood glucose

Hyper- and hypoglycaemia are both common in ICU patients. The former can occur as a result of stress, severe trauma and parenteral nutrition. Hypoglycaemia can occur in septic, toy-breed and juvenile patients, as well as those given insulin and those with some neoplasms, endocrinopathies, hepatic failure and toxin ingestion (Table 1). Hypoglycaemic patients will need frequent monitoring to check for resolution once treatment has been given and, if the underlying cause is not immediately resolved, further frequent monitoring is required to check that the condition does not recur. Any patient with the potential for hypoglycaemia should have its blood glucose levels checked if dull mentation or more severe neurological signs develop.

## Electrolytes

Electrolyte abnormalities are common in ICU patients (Table 1). Once an actual or potential electrolyte disturbance has been identified, monitoring can be expensive and so careful consideration should be made as to how frequently it is required. By taking into account the likely underlying reason for the abnormality, how severe the clinical signs are, how aggressive corrective therapy is and the concerns about overcorrection (eg, converting a hypokalaemic patient to a hyperkalaemic one) or too rapid correction (eg, of hyponatraemia), an appropriate monitoring frequency can be determined; for a relatively stable case on intravenous fluid therapy only then once daily monitoring is fine but for patients with very dynamic disturbances, monitoring may need to take place even up to hourly for a short period.

## ECG

ECG monitoring should be considered in patients with significant abnormalities in heart rate (dogs: above 180 bpm or below 50 bpm, cats: above 240 bpm or below 140 bpm) or rhythm to characterise the disturbance further. Continuous monitoring using a multiparameter monitor is a useful tool in patients with current or recent cardiovascular instability to ensure a response to treatment and to detect any deterioration rapidly.

Determination of a patient's cardiac rhythm is an important element of advanced life support during cardiopulmonary resuscitation (CPR) to determine whether drug therapy or defibrillation is indicated.

Bradyarrhythmias are defined as a heart rate below 60 bpm in dogs and 100 bpm in cats, with associated clinical signs. Sinus bradycardia is common in critically ill patients, secondary to the underlying disease present, but assessment of an ECG is necessary to distinguish this from more serious conduction disturbances such as atrioventricular block or sick sinus syndrome. Bradycardia may also result from severe electrolyte disturbances (such as hyperkalaemia) or neurological dysfunction. Further investigation may therefore be warranted.

Tachycardia is also very common in ICU patients. Most frequently it is sinus in origin (and therefore regular) and is commonly associated with shock. Tachyarrhythmias (both regular and irregular) may also be cardiac in origin, requiring ECG interpretation to distinguish between supraventricular and ventricular rhythms, and decide on the most suitable treatment.

## Arterial blood pressure

Blood pressure may be measured indirectly using either Doppler or oscillometric techniques, or directly via placement of an arterial catheter. Blood pressure should be measured at least once a day in the majority of ICU patients, and the result assessed in conjunction with other perfusion parameters and overall patient condition. Continuous direct arterial blood pressure measurement is occasionally indicated in patients with severe haemodynamic abnormalities to assess the response to therapy and to monitor for any deterioration.

Blood pressure is maintained by a combination of patient heart rate, stroke volume and systemic vascular resistance. Hypotension is common in critically ill patients and may occur if there are abnormalities in any of these elements, resulting in compromised tissue perfusion. A Doppler measurement of less than 90 mmHg or oscillometric mean arterial pressure of less than 60 mmHg is considered to be diagnostic of hypotension. Treatment is aimed at resolving the underlying cause via fluid therapy, heart rate control, vasopressors or inotropes.

Hypertension is less common in critically ill patients but no less important. A blood pressure above 180 mmHg puts a patient at high risk of damage to end-target organs such as the central nervous system, eyes, heart and kidneys, and should be treated if thought to be genuine and persistent. True hypertension is commonly associated with renal or adrenal disease but this must be differentiated from more transient elevations in blood pressure, which may be due to pain or a response to stress/excitement.

## Pulse oximetry

Pulse oximetry is a non-invasive way to measure patient oxygenation and can be used to monitor for respiratory failure. A pulse oximeter measures the oxygen saturation of arterial blood as a percentage using the difference in red and infrared light absorption by oxygenated and deoxygenated blood. A pulse oximetry reading of over 95 per cent on room air is considered to be normal. Values less than 95 per cent (corresponding to a partial pressure of oxygen [$PaO_2$] below 80 mmHg) are consistent with hypoxaemia, and those less than 90 per cent (corresponding to a $PaO_2$ below 60 mmHg) are highly concerning and consistent with severe hypoxaemia.

Pulse oximetry may be used in the assessment of patients with respiratory distress to determine the presence and severity of any compromise in oxygenation although it is relatively insensitive for this purpose, as noted above. It may also be used as a marker of perfusion when applied continually to an ICU patient.

Common sites for placement of the pulse oximeter probe include the tongue (in anaesthetised patients), or any hairless, minimally pigmented location (such as the pinnae, lip, prepuce, vulva or interdigital space). The machine may display the result as a single number or may show a waveform or stack of bars as a marker of the pulse quality. The measured heart rate should match that of the patient to ensure an accurate result is being obtained. False or inaccurate readings are common in cases of patient movement (including tremors or shaking), poor perfusion, anaemia, skin pigmentation, electrical interference or haemoglobinopathies, such as carbon monoxide toxicity.

## Blood gas analysis

Abnormalities in acid-base balance are frequently seen in patients requiring intensive care. Blood gas analysis may provide useful information as to the underlying disease process, its severity and any response to treatment. The results are obtained rapidly and can detect life-threatening abnormalities within minutes. Blood gas analysis may be performed on venous or arterial blood; venous samples only provide information on acid-base disorders and ventilation, whereas arterial blood provides additional information on oxygenation. Any peripheral artery may be used for sampling, although the dorsal metatarsal artery is most commonly used. The $PaO_2$ should be approximately five times the inspired oxygen concentration in air: for example, a patient breathing room air (21 per cent oxygen) should have a $PaO_2$ of 5 x 21 = 105 mmHg.

Blood pH is normally tightly regulated to avoid injury to the body tissues and organ dysfunction. Normal blood gas values are shown in Table 2. Any abnormality warrants further assessment.

Common acid-base disorders are shown in Table 3. Treatment of the underlying cause is indicated to correct any acid-base disturbance in the majority of cases.

## Capnography

End-tidal carbon dioxide ($ETCO_2$) can be measured non-invasively using a capnograph in a patient with an endotracheal tube in place. A normal $ETCO_2$ in dogs and cats is around 35 to 45 mmHg. The normal gradient between $ETCO_2$ and arterial partial pressure of carbon dioxide ($PaCO_2$) is typically less than 5 mmHg in small animals; thus, capnography can be used to assess patient ventilatory function.

Capnography has many additional roles in the ICU patient, including the ability to confirm correct placement of an endotracheal tube or nasogastric feeding tube, and to monitor the efficacy of cardiac compressions during CPR where a minimum target of 15 mmHg should be achieved to maximise the chance of return of spontaneous circulation. An abrupt decrease in measured $ETCO_2$ to (near) zero values is suggestive of equipment dislodgement or cardiac arrest and should prompt immediate patient assessment.

Common causes of increased $ETCO_2$ in ICU patients include:

- Hypoventilation due to analgesic or anaesthetic drug administration;
- Upper airway obstruction;
- Neurological dysfunction;
- Atelectasis following prolonged recumbency.

$ETCO_2$ may also be increased secondarily to an increase in carbon dioxide production as a result of pain, anxiety, shivering, seizures and hyperthermia.

A progressive increase in the difference between $ETCO_2$ and $PaCO_2$ values typically represents an increase in dead-space ventilation within the lung, which is usually consistent with progressive respiratory dysfunction that may prompt more aggressive management.

Waveform analysis may also be useful (see Further reading).

## Patient-side ultrasonography

In contrast to more formal extensive patient ultrasonography assessing all internal organs, rapid, focused, patient-side ultrasound examinations are commonly performed on patients in an ICU. These examinations do not require specialist training, can be performed rapidly and can provide valuable information as to the nature of the patient's underlying condition. They are termed FAST scans (focused assessment with sonography for trauma, triage or tracking) and can be used to assess both the abdomen (AFAST) and thorax (TFAST).

The primary objective of the AFAST scan is to detect free fluid in the peritoneal cavity that may occur secondarily to many disease processes seen in ICU patients. This is achieved by placing the ultrasound probe over four sites (right and left flanks, midline over the bladder and subxiphoid site with the probe caudal to the xiphoid process). Serial AFAST scans may detect fluid accumulation over time and can be used to check the progression of pathology. Repeated AFAST scans after fluid therapy has been administered may increase the likelihood of a positive result.

TFAST can be used to detect pericardial effusion, pleural effusion and pneumothorax. The ultrasound probe is placed in five standard locations over the thorax to determine the presence of any air or fluid. With practice, the operator can note the presence or absence of ultrasonographic findings such as the glide sign (its absence is suggestive of pneumothorax), and B-lines (associated with interstitial-alveolar lung abnormalities). TFAST is particularly useful in patients with respiratory distress that are too unstable for more definitive diagnostics such as radiography. The patient-side and brief nature of the TFAST study can yield valuable information in unstable patients.

Patient-side ultrasonography may also be used to assess the left atrium to aortic ratio, a marker of left atrial enlargement. This is best measured using a right parasternal view; a normal ratio is less than 1.5. A subjective assessment of ventricular filling and cardiac contractility may also be made and may be useful in guiding therapy in patients with cardiovascular instability.

## Fluid analysis

Several patients within the ICU may have indwelling drains to aid the management of their condition. It is essential that these tubes are managed correctly to prevent additional patient morbidity (see the nursing article on pp 25-29 in this supplement). Thoracostomy tubes may be placed in the management of several pleural space diseases, including persistent pneumothorax, chylothorax, neoplastic effusion and pyothorax. Abdominal drains are frequently placed after abdominal surgery to help ensure resolution of the underlying disease process, and aid decision making regarding fluid therapy by accounting for third-space fluid losses that require replacement.

The overall volume of air or fluid produced and the cytological nature of any fluid may be assessed, and both would be expected to improve with disease resolution. For example, for a postoperative case of septic peritonitis:

- The drain fluid volume should reduce significantly over time;
- Cell numbers should decrease and consist largely of non-degenerative neutrophils;
- There should be an absence of bacteria (although bacterial contamination of a drain can occur, meaning that the presence of bacteria in drain fluid does not always mean septic peritonitis is present).

Paired abdominal drain fluid and blood glucose and lactate measurements have been shown not to be useful when monitoring patients (Szabo and others 2011).

The drain should be kept in for as long as it is productive (>5 to 10 ml/kg every 24 hours), then removed to minimise the risk of nosocomial infection.

## Urine output

Urine output is a useful parameter for monitoring renal function in ICU patients. Normal urine output in an appropriately perfused and hydrated patient is usually 1 to 2 ml/kg/hour. Urine output may be below this in cases of hypoperfusion as a normal physiological response to conserve body fluid or pathologically in cases of oligoanuric acute kidney injury (AKI). Patients requiring intensive care are often at high risk of developing AKI, which may be multifactorial in origin. Possible underlying causes include:

- Previous episodes of hypotension secondary to shock or anaesthesia;
- Administration of nephrotoxic drugs as part of the patient's therapy;
- Systemic inflammation;
- Other systemic underlying diseases.

Early recognition of altered urine output can prompt thorough patient evaluation for ongoing hypoperfusion or kidney injury, allowing aggressive management.

Urine output can occasionally be increased above normal levels. Reasons for this include:

- Iatrogenic volume overload;
- Cats with postobstructive diuresis following resolution of an obstruction within the urinary tract;

- Patients with polyuric AKI or medullary washout following a prolonged period of fluid therapy.

Recognition of pathological polyuria is important to guide fluid therapy and prevent inadvertent dehydration.

Urine output may be measured via placement of an indwelling urinary catheter and closed collection system. Other techniques include direct measurement of urine being naturally voided or weighing incontinence sheets in non-ambulatory patients. Patient bodyweight may also be used as a marker of altered urine output, as described above.

Urine sampling and analysis is also indicated in patients in which a urinary tract infection is suspected, or when a patient develops a fever during hospitalisation.

## Summary

Canine and feline veterinary medicine has progressed hugely over the past few decades allowing the successful management of critical patients. Dogs and cats requiring intensive care have serious disease processes but with appropriate monitoring, effective treatment and also financial and emotional commitment from their owners, many of these animals can do very well. The demands for a veterinary practice to run an effective ICU are great (see article on pp 2-5 of this supplement), but these patients can be some of the most rewarding to treat.

## Quiz: Monitoring small animal patients in the intensive care unit

1. An arterial blood sample from a dog under general anaesthesia has a pH of 7.010, with a $HCO_3^-$ of 27 mmol/litre and a $PaCO_2$ of 80 mmHg. What would the best description of its acid-base status be?
a. Metabolic acidosis
b. Metabolic alkalosis
c. Respiratory acidosis
d. Respiratory alkalosis

2. What would the likely cause and appropriate treatment be for the dog in question 1?
a. Hypoventilation due to increased anaesthetic depth; decreased inhalant agent concentration
b. Hyperventilation due to response to painful surgical procedure; administer an opioid analgesic
c. Acute kidney injury due to poor renal perfusion; administer a bolus of Hartmann's solution
d. Lactic acidosis due to hypovolaemia due to blood loss; administer a bolus of Hartmann's solution

3. Which of the following toxins can cause hypoglycaemia?
a. Xylitol in sugar-free chewing gum
b. Bromethalin in rodenticide
c. Onions
d. Avocado

4. What is the most accurate way of detecting and monitoring hypoxaemia?
a. Pulse oximetry
b. Capnography
c. Electrocardiogram analysis for evidence of myocardial hypoxia
d. Arterial blood gas analysis

**Answers**
1. c. See Table 2.
2. a. A respiratory acidosis under general anaesthesia is likely to be due to overdose of anaesthetic drugs causing hypoventilation and so anaesthetic depth should be decreased.
3. a. See Table 1. The others are all toxic to dogs but do not cause hypoglycaemia.
4. d. Pulse oximetry is more readily available and can be helpful, but is prone to inaccurate readings. Capnography is useful for assessing carbon dioxide levels in the patient $CO_2$ but gives no information on oxygen. Analysis of an electrocardiogram would not be helpful.

### References


MATHEWS, K., KRONEN, P. W., LASCELLES, D., NOLAN, A., ROBERTSON, S., STEAGALL, P. V., WRIGHT, B. & YAMASHITA, K. (2014) Guidelines for recognition, assessment and treatment of pain. *Journal of Small Animal Practice* **55,** E10-E68

PLATT, S. (2005) Evaluation and treatment of the head trauma patient. *In Practice* **27,** 32

SILVERSTEIN, D. C. & HOPPER, K. (2015) Small Animal Critical Care Medicine. 2nd edn. Saunders Elsevier

SZABO, S. D., JERMYN, K., NEEL, J. & MATHEWS, K. G. (2011) Evaluation of postceliotomy peritoneal drain fluid volume, cytology, and blood-to-peritoneal fluid lactate and glucose differences in normal dogs. *Veterinary Surgery* **40,** 444-449


### Further reading


BOYSEN, S. R. & LISCIANDRO, G. R. (2013) The use of ultrasound for dogs and cats in the emergency room: AFAST and TFAST. *Veterinary Clinics of North America: Small Animal Practice* **42,** 773-797

IRIZARRY, R. & REISS, A. (2009) Arterial and venous blood gases: indications, interpretations, and clinical applications. *Compendium on Continuing Education for Practicing Veterinarians* **31,** E1-E7

LISCIANDRO, G. R. (2011) Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *Journal of Veterinary Emergency and Critical Care (San Antonio)* **21,** 104-122


### Further information

Graphic examples of normal and abnormal capnograms can be found at www.capnography.com

**doi: 10.1136/inp.i5503**

**Karen Humm** graduated from the University of Cambridge in 2001 and spent two years in small animal practice before completing an internship at Liverpool university. She then worked at an emergency clinic before starting a residency at the Royal Veterinary College in emergency and critical care. She gained the American Diploma in Veterinary Emergency and Critical Care in 2008 and is now a lecturer in small animal emergency and critical care at the RVC. Her areas of interest include veterinary teaching, fluid therapy and transfusion medicine.

**Lindsay Kellett-Gregory** graduated from the Royal Veterinary College in 2004. She spent two years in private practice before completing an internship at the RVC followed by a residency in emergency and critical care medicine at the University of Pennsylvania, USA. She is a boarded diplomate of the American College of Emergency and Critical Care and also an RCVS Recognised Specialist. She currently works as a lecturer in emergency and critical care at the RVC and her interests include sepsis, transfusion medicine and renal replacement therapies.

# Monitoring small animal patients in the intensive care unit

Karen Humm and Lindsay Kellett-Gregory

*In Practice* 2016 38: 12-17
doi: 10.1136/inp.i5503