The aim of the Clinical Conundrum is to present a thought provoking case to the reader and allow in-depth discussion of the intricacies of the case presented. In particular it is hoped that cases will challenge the reader to consider a dilemma, be it a diagnostic challenge or a treatment decision and to work through it to a logical conclusion. As a result the clinical conundrum has become one of Companion’s most successful and popular CPD features, providing thought provoking and engaging discussion of clinical problems.

Case selection
The aim of the clinical conundrum is to present clinical scenarios which are encountered in small animal practice and discuss briefly any poignant features of the case. The conundrum can focus on the complete case management or one aspect of the case management in more detail.

Example of how a case may be used in a clinical conundrum:

- **A problem orientated approach to a challenging diagnosis.** In this instance the emphasis would be to challenge the reader to construct a problem list, consider relevant differential diagnoses and ultimately achieve a diagnosis based on the information gained during investigation. In this type of report emphasis should be focused on the rationale for choosing a given test and a logical approach to eliminating all other differential diagnoses.

- **Treatment or surgical dilemma.** In this type of case the diagnosis may have already been made or be relatively simple to reach. The focus of this type of conundrum would be to challenge the reader to decide how they would gather the information to decide on a treatment plan and to select and justify choice of treatment based on the information obtained. This type of conundrum should not simply be a review of the literature.
instead the emphasis should be placed on how the case was assessed and how these particular findings influence treatment choice.

- **Conundrums that focus on one aspect of a complicated case.** Most suitable for a more focused evaluation of a single aspect of an individual cases such as anesthetic considerations and pre-anesthesia stabilization for a clinical presentation or the subtleties of diagnostic imaging interpretation.

An unusual diagnosis although interesting does not necessarily mean that a case will be a suitable to present as a clinical conundrum, as the final diagnosis is often one of the least important parts of the conundrum. Indeed the cases which make the best conundrums discuss a presentation thoroughly, logically progress through a case and achieve a robust diagnosis or treatment choice. It is the dilemma regarding diagnostic or treatment progression which is important rather than the diagnosis in and of itself. The editorial team are more than happy to advise on the selection of cases for this feature and particularly welcome and encourage submissions from those in general practice.

**Style**

Case reports should be structured to encourage the reader to consider different aspect of the case or diagnostic procedure as the clinical picture unfolds. This is easiest to achieve by posing questions which outline the author’s thought processes at the time when the actual investigation was taking place and the answers to which dictate the next step in the clinical management of the case. Thus the reader gains an appreciation of the logical progression through the case and, just like in the clinical situation, is not aware of the end diagnosis or final decision at the outset.

Understandably this format is easier to follow for some cases and in some clinical disciplines than others. However the format has been already been successfully adapted to a variety of different scenarios and the editorial board are always willing to assist with the construction of a conundrum around a suitable case.

An example of how a clinical conundrum, in which the focus is achieving a final diagnosis, could be structured as outlined below. Depending on the type and focus of a conundrum the format will of course vary.

- **Initial presentation information.**
  A brief clinical history to include signalment, presentation and examination findings

- **Question:** Create a problem list?
  - **Answer:** A short list summarizing the most important clinical findings

- **Question:** Consider the differential diagnosis for your problems. Can your differentials be prioritized based on the history and physical examination findings?
  - **Answer:** The author should outline their thought processes as if the case was in front of them. For example “evidence of stranguria and dysuria made the lower urinary tract the most likely source of the haematuria”

- **Question:** Construct a diagnostic/treatment plan.
  - **Answer:** Should outline which tests and treatments are appropriate in particular why a given test/treatment was been chosen. For example “a biochemistry profile was performed to assess for metabolic causes of seizures such as hypoglycemia and hypocalcaemia”. Any monitoring or ongoing treatments whilst tests are performed should also be outlined

- **Results of investigations.**

- **Question:** How your interpretation of the test results help you refine your differential diagnosis?
  - **Answer:** The results should be interpreted and the relevance of new findings to case management and diagnosis discussed. The problem list and differential diagnosis list may be reviewed and amended if necessary.

- **The process of investigation, interpretation of results and evaluation of patient progression continues until a final diagnosis is reached.**

- **A brief summary of the final diagnosis and review of the pertinent points of the case and the literature conclude the conundrum.**
Preparing a submission

In total authors should aim for a piece of 1400–2000 words in length with a 1–5 illustrative pictures. Although Companion has a less formal style compared to formal case reports colloquial language should be avoided. The animal should not be referred to by its name for example and progression through the case should not use dates for different examinations. Instead this should be day 1 for initial presentation and so on, depending on progress. Companion uses the BSAVA style with the –ize rather than –ise suffix. Any clinical data should be presented in SI units; further details of SI unit conversions can be found on the BSAVA website:

www.bsava.com/Resources/Conversiontables

Illustrations

As high resolution images as possible should be submitted alongside the conundrum. We will be able to help format images were needed, so don’t worry too much as to the file format. Images should not contain any identifying information (for example the owner or animals name, the referring practice etc). Permission should be sort to include pictures of people with in any images prior to publication.

References

Given that the emphasis of this feature is problem solving, references are not usually required unless they are integral to the problem solving involved. When specific literature is stated (for example a study has shown that cats are much more intelligent than dogs) then this should be referenced, using the same style as for the JSAP using the Harvard form as follows.

When references are cited in the text, the name of the author and the year should be in brackets, e.g., (Smith 1980). If the author’s name is an integral part of the sentence, the date only is placed in brackets, e.g., as reported by Smith (1980). For more than two authors, (Smith et al. 1980) should be used. Where several references are quoted together, they should be placed in chronological order as they are referred to in the text but alphabetical of the first author’s name. Companion will list the references online and within e-Companion, they are not printed in the text, so there use should be as limited as possible.

The reference list at the end of the submission should be set out as follows:


References to books should be listed as follows:


Submitting a Clinical Conundrum

Please email articles for submission to companion@bsava.com providing illustrations as separate graphic files these can also be embedded within the text of a document as needed. An author picture (head and shoulders portrait style) should also accompany the submission in as higher a resolution as possible.

Following initial review for suitability and style, the editorial board will then forward submissions for peer review. Review time is dependent on reviewer availability but it is intended that submissions be reviewed within 6–8 weeks from submission. An honorarium (currently £150) is payable on final acceptance of the article, provision of all figures/pictures in a suitable format and submission of an invoice.

The editorial team are more than happy to advise on the selection of cases for this feature, the construction of a conundrum around a suitable case and the refining of submitted work. If you have an idea for a conundrum but aren’t sure how to proceed please do contact us at companion@bsava.com.

Examples of previous Clinical Conundrums follow...
A 3-year-old male neutered Domestic Shorthaired cat presented with a wound in the right axilla that had previously been sutured on two occasions and unfortunately had dehisced on both occasions. The cat had been missing for 6 weeks prior to this injury and usually wore a collar, which was missing when the cat returned, leading to the presumption of a potential collar injury as the cause of the wound.

At presentation the cat was bright and alert. Clinical examination revealed a heart rate of 164 beats per minute, a respiratory rate of 24 breaths per minute and pink mucous membranes. The cat was in good condition with a body condition score of 5/9.

The full-thickness right axillary wound measured 5 cm by 4.5 cm and was lined with chronic granulation tissue. The wound extended from the lateral and ventral aspects of the thorax to the caudal and medial aspects of the right proximal brachium (Figure 1). The wound included much of the area normally covered by the axillary skin fold. There was a small amount of green discharge from the wound, which was malodorous. The remainder of the physical examination was normal.

Create a problem list for this patient

- A non-healing axillary wound with possible infection

What are the possible underlying causes for a non-healing wound?

Factors relating to the wound

- Chronicity – the longer a wound is left open, the greater the chance of bacterial multiplication and therefore infection. Desiccation of tissues, tension, prolonged inflammation and reduction in contraction of the wound are also factors that contribute to chronicity
- Contamination – this may include normal skin flora as well as more resistant organisms such as meticillin-resistant Staphylococcus aureus
- Underlying nidus of infection – for example, due to road dirt, bone sequestrum or any foreign material
- Type of injury – crush, tear and thermal injuries can be particularly damaging to the surrounding tissue
- Abnormal tissue in the wound – for example, neoplastic cells
- Anatomical area – high motion areas, pressure points, tight skin, shear forces between the skin and subcutis, and removal of subcutaneous tissue in the axillary and inguinal regions

Patient factors

- Pre-existing concurrent disease – for example, anaemia, uraemia, hypoproteinaemia and coagulopathies
- Concurrent trauma leading to poor perfusion due to shock
- Infectious agents – for example, feline immunodeficiency virus (FIV) and feline leukaemia virus (FeLV) infection
- Poor nutritional status
- Endocrinopathies – for example, diabetes mellitus, hyperadrenocorticism and hypothyroidism
- Neoplastic disease and catabolic status
- Medication – for example, corticosteroids

Surgeon factors

- Inappropriate or poor surgical technique
- Inexperienced in dealing with complex non-healing wounds
- Poor asepsis
- Poor wound management prior to surgery
What investigations should be performed?
A complete blood count (CBC) and biochemistry panel, as well as FeLV and FIV tests, should be performed to identify any concurrent systemic diseases. Haematology and serum biochemistry were unremarkable. FeLV and FIV tests were negative.

A swab should be taken from the wound and submitted for culture and sensitivity testing. This allows assessment of possible concurrent infections, which could be the cause of, or contributing to, non-healing of the wound. A profuse growth of *S. pseudintermedius* was cultured from the swab, which was sensitive to co-amoxiclav.

How do you interpret these results?
These results exclude metabolic and viral causes for the non-healing of the wound. The profuse growth of *S. pseudintermedius* is likely to be a secondary opportunistic infection.

What are the most likely reasons for this wound not to heal?
There are likely to be several factors contributing to the non-healing of this wound. The anatomical area is a major contributory factor. Tension and motion forces are likely to be a significant cause of non-healing of a wound near to or overlying a joint that has a large range of motion. Friction forces, such as those caused by skin-to-suture line contact, also occur in the axilla. However, it is not only tension and friction in the axilla, but also shear forces within the axillary skin fold itself that contribute to the non-healing of a wound. The skin and subcutaneous tissues move independently and may cause the wound not to heal, and problems such as chronic pocketing wounds are often seen in these regions. Poor regional vascularity and chronicity are also probably implicated. The presence of foreign material, such as hair shafts, in the wound bed may also play a part. Due to the position of these wounds and their exudative nature, constant licking of the area may also be a contributory factor.

How would you manage this case?
For any wound closure, the simplest option to achieve a functional outcome should be considered first. Second intention healing is simple, but is not an option in this case due to the constant movement in the axillary region and chronic time frame. Second intention healing involves contraction and epithelialization, and excessive wound contraction in this area would fail to result in a functional outcome.

Primary apposition would be the next simplest approach and would also allow reconstruction of the axillary skin fold (Figures 2 and 3). The more surgical procedures that are carried out, the more the remaining traces of the elbow skin fold are obliterated, which is why this technique could not be used in this case. Restoring the skin fold eliminates excessive tension across the wound and also avoids friction by ensuring that most of the suture line lies outside the axilla (Figures 4 and 5). This is achieved by undermining and separating the skin that becomes adhered to the caudal and medial brachium and the lateral thorax.
As the wound in this case has dehisced twice following primary closure, primary apposition is not a feasible option for this patient. The skin in this region is already under tension due to the previous surgery, which involved debridement and primary apposition. Movement of the forelimb also contributes to tension across a suture line in the axillary region.

Options to minimize tension, in order of increasing complexity, include:

- Use of a subdermal plexus flap (single pedicle advancement flap)
- Use of an axial pattern flap

The recruitment of extra skin decreases dynamic tension in the area and the positioning of the suture lines outside the axilla prevents skin-to-suture line contact. Omentum can also be utilized in this case to enhance the healing potential. The presence of omentum aids healing by increasing vascularity via the release of angiogenic factors, haemostasis, enhancement of immunity, absorbing tissue fluid and by obliterating dead space.

After careful consideration of the options for surgical management, and following discussion with the owner, debridement of the chronic granulation tissue, creation of an omental pedicle flap and wound reconstruction with a local advancement flap (subdermal plexus flap) was performed.

Intravenous co-amoxiclav (20 mg/kg) was administered approximately half an hour prior to surgery. Under general anaesthesia, the chronic granulation tissue was excised from the wound, including the rim of epithelialization from the wound edge. A cranial midline laparotomy was performed, the dorsal leaf of omentum identified (Figure 6) and dissected free from pancreatic and splenic attachments to create an omental pedicle (Figure 7).

The omentum was handled carefully, and care was taken to avoid excessive handling or twisting of the pedicle. A subcutaneous tunnel was created using forceps between the abdominal wound and axillary wound. The leading edge of the omental pedicle was advanced through the tunnel and used to fill the axillary deficit and tacked to the axillary wound bed (Figure 8).

A single pedicle advancement flap using the skin from the lateral thoracic wall was created to cover the skin defect (Figure 9), as this was the simplest reconstruction to perform. A thoracodorsal axial pattern flap may have been a better option in this case as the vascularization of an axial pattern flap is more...
Figure 8: After advancing the pedicle through the subcutaneous tunnel from the abdomen to the axilla, the axillary defect is packed with omentum. The omental pedicle is tacked to the axillary wound bed using simple interrupted sutures of 2 metric polyglactin 910.

Co-amoxiclav (12.5 mg/kg orally q12h) and meloxicam (0.05 mg/kg orally q24h with food) were given postoperatively for 1 week due to the culture results of the initial discharge from the wound and to provide analgesia. Five days following surgery, 1.5 cm of the leading edge suture line of the flap nearest the forelimb broke down. This was debrided and re-sutured under general anaesthesia. The sutures were removed 14 days postoperatively, and the wound healed uneventfully 14 days later.

The cat was re-examined 4 months later when the owner noticed that there was a ventral swelling. A hernia was palpated and the cat underwent surgery to repair the defect. The axillary area had healed very well with good hair regrowth. The cat continued to do well following repair of the incisional hernia.

Discussion

As seen in this case, the combination of omentum together with a single pedicle advancement flap/subdermal plexus flap can be used to enhance healing potential. The presence of omentum aids healing by increasing vascularity via the release of angiogenic factors, haemostasis, enhancement of immunity, absorbing tissue fluid and obliterating dead space. Lascelles et al. (1998) reported the results of omental flaps combined with wound closure to treat chronic axillary wounds: 7 of 10 of their cases went on to heal but there was a high incidence of partial dehiscence, requiring further surgery (8 of 10 cases). This suggests that omentalization alone is insufficient in these cases as excessive tension across the suture line leads to dehiscence; single pedicle advancement flap creation reduces this risk.

There are case reports in the veterinary literature detailing the use of an omental flap with an axial pattern flap. One such report by Gray (2005) described the use of an omocervical axial pattern flap with an omental flap (due to the questionable viability of the thoracodorsal artery in this case), which healed successfully. Lascelles and White (2001) detailed the use of a thoracodorsal axial pattern flap with an omental flap in 10 cases. In 1 of the 10 cases, the axial pattern flap dehisced and in another the donor site dehisced; however, healing did occur in all 10 cases.

In this case, the skin-to-suture line contact contributed to the partial dehiscence of the...
leading edge of the single pedicle advancement flap nearest to the axilla, which is the edge furthest away from the blood supply and under the most tension. Any tension across a wound in the axillary region will lead to dehiscence. A single pedicle advancement flap should be created with a greater base width to flap length ratio. A larger base width flap may also inadvertently include larger cutaneous vessels, which are more robust and reliable.

The complication of the hernia may have been avoided by using a paracostal abdominal incision. The study by Lascelles et al. (1998) documented 2 of the 10 cases developing incisional herniation; however, one cat had a paracostal abscess associated with a paracostal incision.

References are available online and in e-companion.

AVAILABLE FROM THE BSAVA

BSAVA Manual of Canine and Feline Wound Management and Reconstruction
2nd edition
Edited by: John Williams and Alison Moores

Decision-making in wound closure is just one of the topics discussed in the BSAVA Manual of Canine and Feline Wound Management and Reconstruction. The Manual places emphasis on practical decision-making, underpinned by an understanding of the biological wound healing process.

- Practical decision-making
- Advanced flaps, grafts and microsurgery
- Step-by Step Operative Techniques
- Case examples

“...we have many BSAVA manuals on the shelf, but I can see myself needing this one more than most. If you don’t have the latest edition, treat yourselves to it now...” Veterinary Times

Member price: £49.00
Non-member price: £75.00
e-Book also available
Clinical conundrum

Lizzy Conway, an intern at Dick White Referrals, invites companion readers to consider the causes of pelvic limb collapse in a young Miniature Schnauzer.

**Cardiovascular causes**
- Obstruction to flow (causing forwards failure)
  - Aortic stenosis
  - Pulmonic stenosis
  - Obstructive mass lesions
- Pulmonary hypertension
- Cardiogenic shock due to tamponade
  - Pericardial effusion
  - Pericarditis
- Hypoxaemic cardiac disease (due to right-to-left shunting)
  - Eisenmenger’s physiology (atrial septal defect (ASD) or ventricular septal defect (VSD) with concurrent pulmonary arterial hypertension)
  - Tetralogy of Fallot
  - Reverse patent ductus arteriosus (PDA)
- Arrhythmias

**Other hypoxic causes**
- Respiratory disease (generalized hypoxaemia)
  - Reduced ventilation (e.g. upper respiratory tract obstruction)
  - Alveolar diffusion disturbances (e.g. pulmonary oedema)
  - Ventilation/perfusion (V/Q) mismatch (e.g. secondary to pulmonary thromboembolism)
- Local hindlimb hypoxia
  - Vascular occlusion
    - Thrombosis
    - External compression (mass effect)

Other possible causes of pelvic limb weakness, considered unlikely in this case, include:
- Neuromuscular disorders
  - Myopathies (e.g. myositis, exertional, inherited myopathies)
  - Myasthenia gravis
  - Neuropathies (e.g. polyneuropathies, endocrine or toxic neuropathies)
- Metabolic causes
  - Hypoglycaemia
  - Electrolyte abnormalities
    - Hyper-/hypocalcaemia
    - Hyper-/hyponatraemia
    - Hypokalaemia

Create a problem list based on the history and clinical examination
- Intermittent bilateral pelvic limb weakness, associated with excitement/exertion

**What are the differential diagnoses?**
The differential diagnoses for pelvic limb weakness and collapse include neurological, metabolic, musculoskeletal, respiratory and cardiovascular disorders. In this case, the orthopaedic and neurological examinations revealed no abnormalities. Based on the intermittent and progressive nature of the episodes, cardiovascular and regional hypoxic disease were considered most likely.

**Based on the clinical presentation, what initial tests would you perform?**
A complete blood count, serum biochemistry and electrolyte analysis were performed to check for...
metabolic causes of collapse, such as hypoglycaemia and electrolyte abnormalities. These showed mild and non-specific changes (Table 1). A post-prandial bile acid was assessed to further investigate the raised fasted value; this was within normal limits, suggesting that the raised fasted bile acids likely just reflect recent gallbladder contraction.

Since hypoxaemia and cardiovascular dysfunction were considered the main differentials, an ECG and thoracic radiography were also performed.

<table>
<thead>
<tr>
<th>Biochemistry</th>
<th>Result</th>
<th>Unit</th>
<th>Reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total protein</td>
<td>60</td>
<td>g/l</td>
<td>54–77</td>
</tr>
<tr>
<td>Albumin</td>
<td>34</td>
<td>g/l</td>
<td>25–40</td>
</tr>
<tr>
<td>Globulin</td>
<td>26</td>
<td>g/l</td>
<td>23–45</td>
</tr>
<tr>
<td>Urea</td>
<td>5.5</td>
<td>mmol/l</td>
<td>2.5–7.4</td>
</tr>
<tr>
<td>Creatinine</td>
<td>83</td>
<td>µmol/l</td>
<td>40–145</td>
</tr>
<tr>
<td>Potassium</td>
<td>4.8</td>
<td>mmol/l</td>
<td>3.4–5.6</td>
</tr>
<tr>
<td>Sodium</td>
<td>148</td>
<td>mmol/l</td>
<td>139–154</td>
</tr>
<tr>
<td>Chloride</td>
<td>112</td>
<td>mmol/l</td>
<td>105–122</td>
</tr>
<tr>
<td>Calcium</td>
<td>2.6</td>
<td>mmol/l</td>
<td>2.1–2.8</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.77</td>
<td>mmol/l</td>
<td>0.62–0.9</td>
</tr>
<tr>
<td>Inorganic phosphate</td>
<td>1.3</td>
<td>mmol/l</td>
<td>0.6–1.4</td>
</tr>
<tr>
<td>Glucose</td>
<td>5.8</td>
<td>mmol/l</td>
<td>3.3–5.8</td>
</tr>
<tr>
<td>ALT</td>
<td>70</td>
<td>IU/l</td>
<td>13–88</td>
</tr>
<tr>
<td>AST</td>
<td>25</td>
<td>IU/l</td>
<td>14–105</td>
</tr>
<tr>
<td>ALP</td>
<td>54</td>
<td>IU/l</td>
<td>14–105</td>
</tr>
<tr>
<td>GGT</td>
<td>2</td>
<td>IU/l</td>
<td>0–10</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>8.3</td>
<td>mmol/l</td>
<td>3.8–7.0</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>1.9</td>
<td>mmol/l</td>
<td>0.56–1.14</td>
</tr>
<tr>
<td>Creatinine kinase</td>
<td>209</td>
<td>IU/l</td>
<td>0–190</td>
</tr>
<tr>
<td>Bilirubin</td>
<td>4</td>
<td>µmol/l</td>
<td>0–16</td>
</tr>
<tr>
<td>Fasting bile acids</td>
<td>18.2</td>
<td>µmol/l</td>
<td>0–10</td>
</tr>
<tr>
<td>Post-prandial bile acids</td>
<td>1.6</td>
<td>µmol/l</td>
<td>0–15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Haematology</th>
<th>Result</th>
<th>Unit</th>
<th>Reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC</td>
<td>6.2</td>
<td>10¹²/l</td>
<td>5.5–8.5</td>
</tr>
<tr>
<td>Haemoglobin</td>
<td>15.9</td>
<td>g/dl</td>
<td>12.0–18.0</td>
</tr>
<tr>
<td>HCT</td>
<td>0.48</td>
<td>l/l</td>
<td>0.37–0.55</td>
</tr>
<tr>
<td>MCV</td>
<td>77</td>
<td>fl</td>
<td>60–77</td>
</tr>
<tr>
<td>MCHC</td>
<td>33.4</td>
<td>g/dl</td>
<td>30–38</td>
</tr>
<tr>
<td>MCH</td>
<td>25.7</td>
<td>pg</td>
<td>19.5–25.5</td>
</tr>
<tr>
<td>RCDW</td>
<td>15.1</td>
<td>%</td>
<td>12–13.2</td>
</tr>
<tr>
<td>WBC</td>
<td>11.87</td>
<td>x10⁹/l</td>
<td>6.0–15.0</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>5.9</td>
<td>x10⁹/l</td>
<td>3.0–11.5</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>3.74</td>
<td>x10⁹/l</td>
<td>1.0–4.8</td>
</tr>
<tr>
<td>Monocytes</td>
<td>1.45</td>
<td>x10⁹/l</td>
<td>0.2–1.4</td>
</tr>
<tr>
<td>Eosinophils</td>
<td>0.58</td>
<td>x10⁹/l</td>
<td>0.1–1.2</td>
</tr>
<tr>
<td>Basophils</td>
<td>0.09</td>
<td>x10⁹/l</td>
<td>0.0–0.1</td>
</tr>
<tr>
<td>Platelets</td>
<td>Clumped</td>
<td>x10⁹/l</td>
<td>200–500</td>
</tr>
</tbody>
</table>

Table 1: Biochemistry, electrolyte and haematology results. Abnormal results are highlighted in bold. Smear analysis showed unremarkable cellular morphology, and a manual platelet estimation was normal.

What’s your interpretation of the ECG and radiographs?

The ECG showed a normal sinus rhythm, with large negative QRS complexes in leads I, II and aVL (Figure 1). Calculation of the mean electrical axis showed a marked right deviation (+175°), both of which are suggestive of right-sided cardiac hypertrophy or conduction abnormalities. The thoracic radiographs also support right-sided enlargement, with increased convexity of the right side of the cardiac silhouette, plus rounding of the left ventricular apex (Figure 2).

How do these results refine your differential diagnosis list and what would you do next?

Based on the ECG and radiographic findings, differentials for right-sided cardiomegaly in a young dog include pulmonary stenosis, tricuspid valve dysplasia, pulmonary hypertension and right-to-left shunting lesions. Pulmonary
hypertension may itself be primary (idiopathic) or secondary to various other conditions, including thromboembolic disease, heartworm (*Dirofilaria immitis*), lungworm (*Angiostrongylus vasorum*), left-sided heart disease, congenital systemic-to-pulmonic vascular shunting lesions and primary structural pulmonary diseases, such as interstitial pulmonary fibrosis or chronic obstructive pulmonary disease (COPD).

As this dog had no history of travel abroad, dirofilariasis was considered unlikely. Given the young age, a congenital abnormality was a major consideration. Anatomically, shunting lesions can be intracardiac (such as an ASD, VSD or Tetralogy of Fallot) or extracardiac (such as a PDA), although to cause right-to-left shunting rather than the more usual left-to-right shunting, ASDs, VSDs and PDAs need to be accompanied by pulmonary hypertension (Eisenmenger’s physiology). Blood gases, measured in an arterial blood sample taken from the left dorsal pedal artery with the patient breathing room air, revealed markedly reduced PaO₂ levels of 53 mmHg (reference range: 81–103 mmHg), consistent with a hypoxic cause for the collapse.

**What further investigations may be helpful at this stage?**

Given the presence of dorsal pedal arterial hypoxaemia in a young animal, a congenital right-to-left cardiovascular shunting lesion causing venous admixture with concurrent secondary right-sided pressure overload became a significant possibility. Other differential diagnoses for hypoxaemia, such as ventilation–perfusion mismatch from primary pulmonary disease, were considered less likely given both the clinical presentation of the patient and the lack of pulmonary pathology on the thoracic radiographs.

An echocardiogram was performed to further investigate the changes seen. This showed right ventricular enlargement, with hypertrophy of the right ventricular free wall, and a subjective flattening of the interventricular septum, both consistent with right-sided pressure overload (Figure 3; Videos 2 and 3). Pulmonic stenosis and a right ventricular outflow obstruction were excluded on the basis of a normal pulmonary velocity on interrogation of the pulmonary outflow tract by pulsed-wave Doppler, with the sample gate placed both within the right ventricular outflow tract and just distal to the pulmonic valve.

An additional blood vessel was seen to communicate with the main pulmonary artery near the point of origin of the left pulmonary artery, but continuous flow from this vessel into the main pulmonary artery was not identified on the colour flow Doppler study. The vessel was poorly visualized on both the right parasternal short-axis view at the level of the heart base (Figure 4) and on a tilted left cranial parasternal view.

No evidence of an ASD or VSD was seen, but given that these defects are often small and not visualized on 2D echocardiograms, contrast echocardiography in the form of a bubble study was performed to fully exclude these possibilities. A 5 ml volume of agitated sterile saline was injected into the right cephalic vein, and then sequential imaging of the left side of the heart, left ventricular outflow tract and descending aorta was performed to establish the pattern of flow.

In a normal dog, microbubbles should be seen only in the right side of the heart, following which they are cleared from the circulation within the pulmonary vasculature. In this case, no bubbles were seen in either the left cardiac chambers, or the left ventricular outflow tract or ascending aorta, excluding an intracardiac right-to-left shunting lesion (Videos 4 and 5). However, bubbles were seen entering the abdominal aorta, leading to a diagnosis of a right-to-left shunting PDA (rPDA) (Figure 5; Video 6). Transoesophageal ultrasonography can be used to directly image a PDA, but requires general anaesthesia and a specialized transducer and was not considered necessary for the diagnosis in this case. Similarly, an rPDA can be evaluated by right-heart catheterization and pulmonary angiography or by CT angiography (CTA).

**Discussion**

While PDAs are commonly reported canine congenital heart defects, reverse flow PDAs (where blood shunts from the pulmonary artery into the descending aorta) are much more uncommon and infrequently diagnosed². Right-to-left flow within a PDA may occur for two reasons. Firstly, the flow may be primarily right-to-
finding of differential cyanosis.

Weakness usually only manifests in the pelvic limbs due to the anatomy of the PDA; tissues supplied by the left subclavian artery and brachiocephalic trunk, which arise from the ascending aorta proximal to the point of insertion of the PDA, are unaffected, whilst those tissues supplied by vessels caudal to this point receive a degree of venous admixture from blood shunted from the pulmonary artery. In some patients, differential cyanosis is also seen; this is where the caudal mucous membranes, such as the vulva or prepuce, appear cyanotic, whilst the cranial mucous membranes remain normal.

Secondary polycythaemia is also commonly reported. This occurs due to increased renal erythropoietin production in response to chronic renal hypoxia due to the location of the shunt and associated venous admixture cranial to the renal arteries. This case did not show either of these changes, partly due to the pigmentation of the mucous membranes, and partly because the appearance of cyanosis is dependent on the absolute concentration of haemoglobin, rather than the relative concentration of oxygenated and deoxygenated forms, meaning cyanosis is more likely to be seen in a polycythaemic patient.

It is also of note that while left-to-right shunting PDAs commonly exhibit a left basilar continuous ‘machinery’ murmur, reverse PDAs more usually present without an audible murmur, as in this case. When a murmur is audible with an rPDA, it is usually a faint diastolic murmur associated with pulmonic regurgitation; however, it is more common for splitting of the S2 heart sound to be found.

**How would you treat this dog, and what is the likely prognosis?**

In the more usual left-to-right shunting PDAs, attenuation of the shunt is usually recommended, either by minimally invasive techniques (such as Amplatzer device (ACDO) placement or coil embolization) or by surgical ligation, to reduce the left-sided volume overload and avoid progression to congestive heart failure. This is associated with an excellent prognosis in patients which have not yet developed congestive changes.

However, acute occlusion is contraindicated with an rPDA, as it results in exacerbation of the existing pulmonary hypertension and subsequently right-sided heart failure. In this case, the dog was started on sildenafil (1 mg/kg q12h orally) with the aim of reducing the pulmonary arterial pressure and thus the right-to-left shunting fraction. Sildenafil is a phosphodiesterase type V selective inhibitor, which acts to increase pulmonary vascular concentrations of cyclic GMP, which in turn increases the level of endogenous nitric oxide, a potent vasodilator, and leads to pulmonary artery vasodilatation.

The owner was also advised to restrict the dog’s exercise and limit her exposure to exciting events, to reduce the likelihood of cyanotic episodes.

Regular monitoring every 3–6 months for the development of secondary polycythaemia was also recommended, as this can lead to problems with hyperviscosity including bleeding diatheses, thrombosis, local hypoxia and seizures. For cases that do develop secondary polycythaemia, management with either repeated phlebotomy or treatment with hydroxurea have been described. The prognosis for dogs with rPDAs is very variable; survival of between 2 and 8 years is reported with appropriate management.

**Outcome**

At re-examination 4 weeks later, the owner reported an improved demeanour and exercise tolerance, with only 1 further episode of pelvic limb collapse. A repeat echocardiogram and bubble study showed bi-directional flow through the rPDA, suggesting a reduction in the pulmonary hypertension, and the PCV was still within the normal range. Four months subsequent to this consultation the owner reported no further collapsing episodes with ongoing sildenafil therapy and exercise restriction.

**Acknowledgement**

The author would like to thank Jon Wray for his help with this Clinical Conundrum.
Case presentation
A 2-year-old entire female Cavalier King Charles Spaniel presented with a 2–3 days history of anorexia, weight loss and coughing. The cough was mainly heard at play but the owners had also noticed that her breathing rate was rapid even at rest. She had become less keen to play or exercise over the preceding 24 hours. Thirst, urination and defecation were normal. She was fully vaccinated and wormed regularly. The dog lived on a small holding in a rural location with several other dogs and had never travelled abroad. She had not recently been kennelled and no new dogs had been introduced. No other animals were affected and there was no known access to toxins.

Physical examination revealed a low body weight of 3.75 kg with a body condition score of 2/9 (Figure 1). The dog was quiet but alert and responsive. A pronounced tachypnoea of 120 breaths per minute with a slight increase in expiratory effort was noted, with intermittent mouth breathing but no obvious respiratory distress. Coughing could be induced by tracheal pinch and was soft and non-productive. Auscultation revealed expiratory wheezes, which were particularly audible ventrally on the left-hand side.

The heart rate was regular (120 beats per minute) with good quality synchronous peripheral pulses. No audible murmur or arrhythmia could be heard on cardiac auscultation and there were no obvious areas of dullness or increased resonance on thoracic percussion. Rectal temperature was normal at 38.6°C and mucous membranes were pink and moist with a capillary refill time of less than 2 seconds. Clinical findings were otherwise normal.

Create a problem list based on the dog’s history and physical examination findings
- Tachypnoea
- Cough
- Weight loss
- Anorexia

What differential diagnoses should be considered at this stage?
Tachypnoea and cough are likely to be the primary problems with weight loss and anorexia secondary problems. Causes of tachypnoea and cough can broadly be divided into:

- Upper airway disease (e.g. soft palate elongation, laryngeal paralysis, tracheal collapse)
- Lower airway disease (e.g. acute tracheobronchitis, chronic bronchitis, airway foreign body)
- Pulmonary disease (e.g. pneumonia, pulmonary fibrosis, pulmonary haemorrhage due to trauma or coagulopathy, paraquat toxicity)
- Cardiac disease (e.g. left atrial enlargement, pulmonary oedema)
- Thoracic cage disease (e.g. rib fractures, diaphragmatic rupture)
- Pleural space disease (e.g. pleural effusion, pyothorax).

Other diseases that can cause tachycardia without coughing include anaemia, metabolic acidosis, heat stress and pain.

Upper airway disease is most likely to cause increased inspiratory noise and effort. Pleural space disease causes a restrictive pattern of respiration and dullness on chest percussion/auscultation. The absence of a cardiac murmur or arrhythmia makes cardiac disease less likely in a small-breed dog.

As a result in this case the tachypnoea and soft cough are most likely due to pulmonary disease or lower airway disease.
What initial investigations should be considered?

Blood samples were taken for routine haematology, biochemistry and whole blood clotting time (Tables 1 and 2). Results were unremarkable except for a raised white blood cell count of 27.5 x10^9/l (reference range 6–17 x10^9/l) and mature neutrophilia.

Thoracic radiographs were taken under sedation (0.015 mg/kg acepromazine and 0.1 mg/kg butorphanol given by intramuscular injection) with flow-by oxygen supplementation.

Describe the radiographic changes

There is some rotation of the dorsoventral view (Figure 2A) but the lateral view is well positioned (Figure 2B). Ribs and diaphragm are intact and cardiac outline is within normal limits. Both views show a marked generalized interstitial pattern of the lung fields.
Create a revised differential diagnoses list for cough, tachypnoea and interstitial lung pattern

- Early acute pulmonary oedema.
- Pulmonary infection secondary to viral, bacterial, fungal or parasitic infection.
- Pulmonary fibrosis.
- Pulmonary infiltration with eosinophilia.
- Pulmonary haemorrhage secondary to coagulopathy, neoplasia or trauma.
- Paraquat poisoning.

What further investigations may be helpful at this stage?

Since parasites such as *Oslerus osleri*, *Capillaria aerophila*, *Crenosoma vulpis* and, in particular, *Angiostrongylus vasorum* can cause respiratory disease in young dogs, a faecal sample was submitted to check for lung-worm larvae by Baermann test: the results were negative. (This case presented prior to the availability of the now more commonly available ELISA test.)

Given the list of differentials, priority was given to collecting samples for cytology and culture. The dog was anaesthetized with propofol, given to effect by intravenous injection. A blind bronchoalveolar lavage was performed by passing a 6 Fr urinary catheter down the trachea to the estimated level of the tracheal bifurcation (determined by premeasurement of the catheter against the dog). Two 5 ml aliquots of warmed saline were flushed into the region and gently aspirated. Approximately 5 ml of fluid was retrieved, which was foamy in appearance and contained mucoid material.

FIGURE 3: Smear prepared from the bronchoalveolar lavage sample. (Courtesy of IDEXX Laboratories)

The sample was divided into two portions. One portion was submitted to the laboratory in a sterile plain tube for bacterial culture. After obtaining a sample of the mucoid material using a pipette, the second sample was transferred to a blood collection tube containing EDTA and submitted for cytology. The mucoid material was placed on a clean glass microscope slide and a squash preparation made and submitted to the laboratory for cytology.

What is the organism identified on the smear?

Rare round clear cystic structures containing four or more round basophilic bodies suggestive of *Pneumocystis carinii* cysts were noted on the smear (Figure 3). Cytology otherwise showed thick clumps of neutrophils and fewer macrophages within thick mucus with cellular debris in the background. Clumps of swollen poorly preserved columnar epithelial cells were also noted. A diagnosis of *Pneumocystis carinii* was confirmed by PCR.

Given the list of differentials, priority was given to collecting samples for cytology and culture.

How would you treat this case?

Recommended treatment is with potentiated sulphonamide at 30 mg/kg twice daily for 3 weeks. This is higher than the standard licensed dose rate and informed owner consent was obtained. Successful treatment may lead to an initial worsening of clinical signs due to an inflammatory reaction to dying organisms. In humans anti-inflammatory doses of cortisone have been shown to improve pulmonary function and survival rates. However, treatment in this case consisted of potentiated sulphonamide only and no adverse effects or worsening of clinical signs were seen.

What potential side effects should be considered with potentiated sulphonamide therapy?

Keratoconjunctivitis sicca, polyarthropathy, anaemia, thrombocytopenia and sulphonamide crystalluria are all recognized potential adverse reactions to potentiated sulphonamides. Schirmer tear tests were performed prior to starting treatment then every 3 days. All joints were flexed and palpated daily. Haematology was performed regularly during treatment and urination was observed for any signs of dysuria. No adverse reactions were seen in this case.
Are there any other investigations which might be appropriate in this case?

*Pneumocystis* pneumonia has previously been described in immunodeficient Cavalier King Charles Spaniels (Watson et al., 2006) therefore a blood sample was submitted for immunoglobulin estimation. No deficiencies in IgG, IgM or IgA were detected.

What is the prognosis in this case?

Due to the likelihood of an underlying immune deficiency, long-term prognosis for dogs with *Pneumocystis* pneumonia is guarded to poor. Most cases die or are euthanased within days to months of diagnosis. In this case, however, the dog made a steady recovery and has remained disease-free for over 2 years. Treatment is most effective if started within a week of the onset of clinical signs. This, and/or the lack of demonstrable hypo-immunoglobulinaemia, may be the reason why the dog has done so well so far.