How to improve radiographic quality in practice

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When producing radiographs, different factors influence the final image, including patient positioning, preparation and processing of the film. A standardised technique is important - this will help to recognise the cause of a problem when an artefact is produced. In this article the most important factors that influence in the quality of a radiograph are discussed.

General considerations

Patient preparation

For any radiographic study in small animals, the following factors need to be considered:

- The area of interest should be clean, dry and free of any collars, harnesses, etc.
- Patient restraint is very important. Sedation or general anaesthesia is recommended in most cases to achieve accurate positioning, to reduce the number of retakes and to ensure standard positioning which will ease interpretation (**Figures 1** and **2**). It can be useful to add analgesia to the sedation to minimise any discomfort that might be caused by the patient's condition.
- All radiographic contrast studies require specific patient preparation. This will be covered in a later article.

Positioning aids

Different types of positioning aids are used to facilitate specific positioning and therefore to produce good quality radiographs.

A radiolucent foam mattress to cover the table is an easy and inexpensive solution:

- It allows the animal to lie comfortably on a cold, hard table.
- It reduces the chances of the animal moving while taking the exposure, and therefore decreases the number of re-takes.
- It will improve positioning and reduce rotation of the patient, especially in those with narrow chests or a very thin conformation.
- It minimises the effects of hypothermia in anaesthetised animals.

The mattress should have a waterproof cover, which is easy to wipe. It is very important to remember to keep the surface of the mattress clean to avoid artefacts on the radiograph, and also to reduce the risk of cross contamination between patients. Spilt contrast medium, in particular, can be a problem. The recommended thickness is approximately 2.5cm. This type of foam mattress can also be used for other diagnostic studies such as ultrasound, ECG recording, endoscopy, etc.

Sandbags should also be covered in a waterproof material for the same reasons. It is better if they are not filled with sand to more than 30-40% of their full capacity to allow easier placement and less rigidity around the different body parts. It is useful to have various sizes (width and length) to use in different situations/body parts. For example, a wide but not very long sandbag helps for placing around the axilla to keep a patient in ventral recumbency. A long and thin one will ease limb positioning to pull/support an extremity if wrapped around a joint.

Lucent foam pieces of different sizes and shapes will help to minimise axial rotation of some body parts. A triangular wedge is placed under the sternum in those situations where the whole body is lying on the table and needs be kept parallel to the x-ray cassette (thorax, abdomen, pelvis, and spine). Cylindrical foam pieces are useful to elevate the head above the shoulders; rectangular pieces can be used to raise extremities.

Figure 1: Use of positioning aids in a conscious dog.

Figure 2: Use of positioning aids in a sedated dog.

Long boot ties should only be used in patients under deep sedation or anaesthesia, as they can suddenly move and injure the leg. They are especially useful in orthopaedic radiography when traction is necessary. They need to be tied either above the carpus or tarsus and then traction applied by hanging a sandbag at the other end of the tie. The weight of the sandbag will depend on the size of the animal and the amount of traction required.

Right and left metallic markers are necessary to avoid misinterpretation e.g., determining on which side of a cavity a particular lesion is seen.
One of the most important concepts in any radiographic study is that two orthogonal projections/views should be taken of any body part to allow complete evaluation of size, shape and position of an organ/lesion.

Radiographic technique
Kilovoltage (kV) is selected on the control panel of the x-ray unit. This indicates the penetration power of the x-ray beam. The miliamperage/time (mAs) is a constant that determines the intensity of the primary beam. In those units where it is possible to select the time independently from the mA, the shortest time possible should be selected to avoid blur artefact from voluntary or involuntary movements. If it is not possible to select time and mA separately, the mAs can be reduced and the kV can be increased to compensate. As a general rule, an increase of 15%, or 10 units, in kV is equivalent to double the mAs.

A grid should be used for areas thicker than 10cm. This reduces the amount of scatter that reaches the film and therefore increases the radiographic quality.
To ease patient positioning, the use of a grid that sits underneath the tabletop is better. The tray where this grid is placed is called a 'Potter-Bucky'. This tray moves while the exposure is taken, allowing the absorption of an increased amount of unwanted scatter. If this equipment is not available, a stationary grid can be placed on the top of the cassette.

A regular or fast speed film-screen combination must be used with the grid, as the mAs will have to be increased (the so-called 'grid factor'). A slow film-screen combination can be used in those thin areas where the grid is not necessary (limbs, small heads, feline thorax and abdomen). The quality and detail is improved due to the small size of the fluorescent crystals within the intensifying screen. However, higher mAs will be necessary to produce an image with these slow screens. Fast screens should be used for the thorax or abdomen in large dogs where slow screens would result in poor quality radiographs due to under-penetration because of low unit output or movement blur due to prolonged exposure time. The ideal situation is to have cassettes of various sizes and with different speed film-screen combinations. This might not always be practical or economical and will also depend on the output of the x-ray unit.

Figure 3: Good collimation technique on a mediolateral view of the right hock.

Whether fast or slow screens are used, it is sensible to use the same type of film for all screen types. This avoids confusion and prevents placement of the incorrect film into the wrong cassette. Maintenance of the screens is very important. Regular cleaning will prevent artefacts (screen marks) on the radiographs caused by the accumulation of dirt. Soapy water or specific manufacturer's screen cleaner can be used.

The distance between the x-ray tube and the film is called film-focus distance (FFD) and this is usually 100cm. For thoracic radiography in dogs, it can be increased to 120cm to improve the detail and definition of the fine structures such as the bronchial walls and small blood vessels (by reducing the so-called 'penumbra effect'). The distance between the area of interest and the cassette is called the 'film-object distance' (FOD). It is essential to keep this as small as possible to minimise magnification and loss of definition in the final image.

Processing

Processing is a very important step in obtaining a good quality radiograph. The process should be kept constant and in the best possible conditions. The quality of a radiograph can be easily lost with an inadequate processing protocol.

Manual processing
It is essential to closely follow the set routine, with the indicated times and temperatures for each chemical tank.

- Horizontal systems (trays) are the most economical but it is difficult to avoid oxidation and to keep the chemicals at a constant temperature.
- Vertical systems (tanks) are more expensive but it is easier to maintain the fluids in good condition by avoiding oxidation.

Automatic processing
This form of processing is the quickest and most efficient system. Nowadays, automatic processors are very affordable, but an assessment of a practice's radiographic throughput needs to be carried out before the expense can be justified. An automatic processor needs regular cleaning maintenance to keep its performance at an optimal level.

Equipment and technique for radiography of the skeletal system

Most of the radiographs required for orthopaedics can be produced by any low output radiographic unit. A light beam diaphragm allows accurate collimation to improve the quality of the final image (**Figure 3**) by reducing the amount of scatter reaching the film. The area to be radiographed should be placed onto the cassette as parallel as possible to avoid image distortion (**Figure 4**).

Single emulsion film and screen combinations (mammography systems) have become very popular in veterinary radiography due to the increased soft tissue and bony detail they offer. They are especially useful when identifying foreign bodies within the foot pads. Only small parts should be radiographed with these systems as the requirements for mAs are higher than for any slow film-screen combination.

There are different techniques to calculate the exposure parameters for each body part. These are widely described in the literature. In orthopaedic radiography, high contrast radiographs are indicated. The kV should be low but sufficient to penetrate the area. This maximises the photoelectric effect and allows most of the tissues to absorb the x-rays (range between 50-75kV). The mAs will then be selected depending on the film-screen combination and use of grid. The radiographs should be taken at the end of expiration as there is a longer pause and less risk of movement blur from respiratory movement.
Frequently, the same exposure settings can be used for both orthogonal views, especially in cats. There are exceptions: in the shoulder and elbow, the caudocranial projection will need at least 10% more kV than the mediolateral view. When radiographing long bones it is advisable to include the proximal and distal joints. This will increase the diagnostic potential (e.g., in the case of trauma, to rule out joint lesions such as articular fractures.)

Equipment and technique for thoracic radiography

It is a challenge to obtain good thoracic radiographs in practice, especially when low output x-ray units are used. However, almost any size of thorax can be radiographed with any unit.

High output units

These allow the use of medium speed screens with a grid if necessary. The shortest exposure time possible should be chosen, and the kV should be increased accordingly. This will minimise movement blur and produce a low contrast image, which is ideal for examining the thoracic structures.

Lower output units

There are measures that will help to take good thoracic radiographs, even in large/giant breed dogs using lower exposure settings. These are as follows:

- Use a fast film-screen combination.
- Use a grid for thorax only if it is thicker than 15cm.

Figure 4: To avoid image distortion any area to be radiographed should be parallel to the cassette and perpendicular to the primary beam.

- Reduce FFD to 90-100cm.
- Always take the exposure at the end of inspiration to improve lung inflation and radiographic quality. As the pause in inspiration is short, movement blur can occur if long times are selected.
- Sedation is indicated (if practical) to avoid rapid respiratory movements or panting.
- General anaesthesia permits manual inflation of the lungs and maximises aeration. The advantages for this are:

a. The prevention of artefacts associated with increased lung opacity due to poor inflation (often seen in conscious or sedated patients).
b. The increase of air within the lungs reduces the density of the tissue the primary beam has to penetrate.
c. It allows holding the breath for a long as necessary (within reason) to make the exposure. This minimises the movement blur that is likely when using the prolonged exposure times needed with a low output x-ray unit.

There are also several disadvantages with general anaesthesia:

a. Performing general anaesthesia will depend on the medical condition of each patient.
b. Prolonged lateral recumbency leads to partial collapse of the dependent lung. This effect, called 'hypostatic congestion', is more marked with general anaesthesia, and it will produce increased lung opacity of the dependent lung which can lead to a wrong diagnosis (**Figure 5**). While the animal is in lateral recumbency the heart will drop towards the dependent chest wall making some of the periphery of the ventral lung field

Figure 5: Artefacts due to prolonged recumbency in an anaesthetised patient. Black arrows: hypostatic congestion. White arrows: lung retraction mimicking pleural effusion between the lungs and sternum (asterisks).

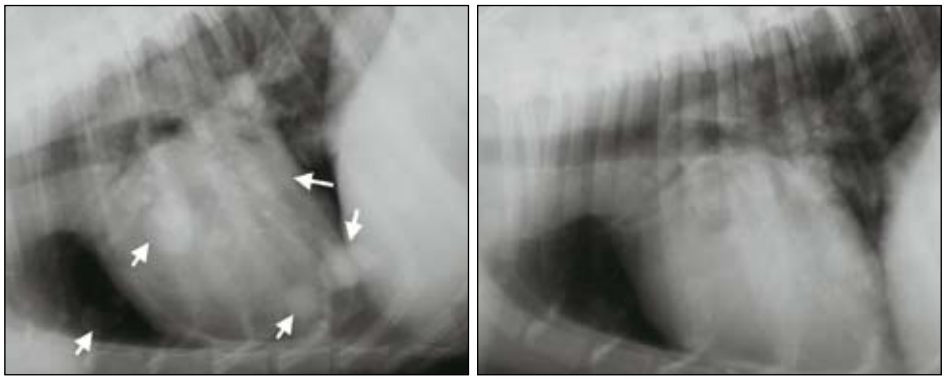

Figure 6: Left lateral recumbency (left) and right lateral recumbency (right) and thoracic radiographs of a medium size dog. Some of the lesions can only be distinguished in one of the views. In this case, the left lateral recumbency projection is more sensitive to detect most of the larger metastatic nodules lesions (arrows).

retract from the chest wall. This should not be mistaken for a pleural effusion. To avoid these unwanted opacities on the radiograph, it is best to take the dorsoventral or ventrodorsal projections before the lateral recumbent views. During any period of inactivity it is recommended to keep the patient in sternal recumbency to allow the lungs to re-expand.

c. Manual inflation should be performed gently to avoid tracheal or lung tissue tear/rupture. For this reason, and to avoid over inflation, it is advisable to use un-cuffed endotracheal tubes in cats. The anaesthetic circuit should have the valve and re-breathing bag at the opposite end of the patient's connection, and should be long enough to allow a person to stand behind the protective screen and/or outside the room to inflate the thorax. Once the valve is closed and gases turned off, the circuit is disconnected from the anaesthetic machine. The person inflating the lungs will indicate to an assistant when to take the exposure while inspiration is held.
d. The valve must then be re-opened and the animal re-connected to anaesthetic circuit.

Positioning

Both fore limbs should be extended cranially to avoid superimposition of soft tissues over the cranial mediastinum. Both hind limbs should be extended caudally. All limbs should be secured with sand bags. A foam wedge is placed under the sternum to avoid axial rotation. The neck should be left in a neutral position to avoid unwanted changes in tracheal location.

The primary beam is centred caudal to the border of the scapula (2.5cm approximately) for any projection. In the lateral view, the beam is centred at 2/3 of the dorsoventral distance to include the ventral skin edges at the sternum. The cranial abdomen should be included in all thoracic projections.

In cases with life-threatening thoracic conditions (e.g., severe dyspnoea), special care should be taken to keep stress levels to a minimum. Horizontal beam radiography may be useful in these cases where minimal restriction is required. The result might not be a perfect radiograph but adequate to make a preliminary diagnosis (e.g., pneumothorax, pleural effusion) and to allow appropriate treatment to be given to stabilise the patient.

Exposure settings

There is high contrast within the thorax due to the amount of air within the normal tissue. To maximise visualisation of the small structures such as bronchial walls and vessels, a low contrast radiograph (with a long grey scale) should be produced. Increasing the kV and reducing the mAs will achieve this. The dorsoventral projection is valuable for examining the cardiac silhouette and for achieving diagnostic images by maximising the aeration of the dorsal lung fields. For the evaluation of lung metastases it is best to perform both right and left lateral recumbency views to assess the lungs on both sides. The dependant lung collapses due to the lack of air, and a soft tissue nodule could be obscured by the artefactual increased opacity of the lung tissue (**Figure 6**).

Figure 7: Right lateral view of the abdomen of a dog. The gas is seen within the fundus. It appears there is an opaque foreign body in the pyloric region.

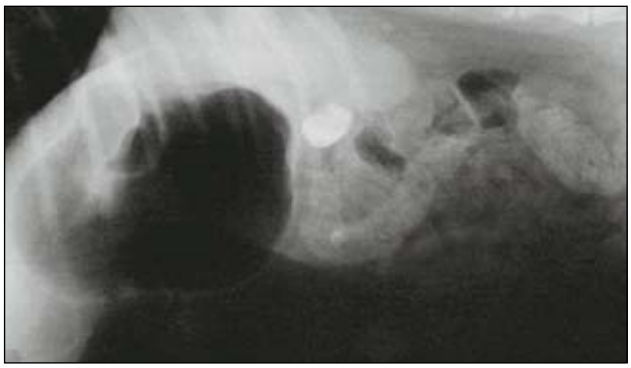

Figure 8: Left lateral view of the abdomen in the same dog. The gas shadow has now moved towards the uppermost structure, the pylorus. The foreign body (stone) is in the small intestine and not the pylorus as previously thought. The excess gas within the stomach could be an indication of obstruction.

Figure 9: Ventrodorsal view of the abdomen showing the presence of gas within the body of the stomach.

Figure 10: Dorsoventral view of the thorax to show the distribution of the gastric gas in the fundus.

Equipment and technique for abdominal radiography

The normal fat deposits within the abdomen (retroperitoneum, mesenterium, falciform fat) provide a good inherent low contrast (long grey scale). To increase the contrast (short grey scale) of the abdominal radiographs, we can use a low kV technique in the same way as explained for the skeletal system, as long as the x-ray unit will allow for the increase in mAs to compensate for the lower kV selected.

The exposure ought to be taken at the end of the expiration where a longer pause and a more natural positioning of the abdominal organs occurs. This minimises the chances of movement blur.

Positioning

Both fore limbs should be extended cranially. Both hind limbs should be extended caudally to avoid superimposition of soft tissues over the caudal abdomen. All limbs should be secured with sand bags. A foam wedge should be placed under the sternum to avoid axial rotation.

In deep chested dogs with a narrow abdomen, it is advisable to perform separate radiographs of the cranial and caudal abdomen as the kV requirements will be very different. For large dogs with a long abdomen, two radiographs might also be necessary to include the entire abdomen.

In vomiting cases with suspicion of an obstruction, both right and left lateral recumbency views will allow the gas within the stomach to move to the non-dependant part and highlight the fundus and pyloric region respectively (**Figures 7** and **8**). Room air can be introduced by a stomach tube if there is no gas within the stomach. Whenever possible, the ventrodorsal and dorsoventral projections will help to complete the gastric study especially after a barium meal. In the ventrodorsal (**Figure 9**) view, the gas will accumulate in the gastric body whereas the air will collect in the fundus on a dorsoventral radiograph (**Figure 10**).

Equipment and technique for radiography of the spine

Only the bony structures of the spinal column are visible on radiography and, in order to minimise the difficulty arising from the complex anatomy, it is essential that accurately positioned lateral and ventrodorsal films are produced. Myelography, epidurography and interosseous venography will help to outline the spinal cord and nerves but they are not a substitute for good quality plain radiographs.

Remember, when taking spinal radiographs:

- Screen films are beneficial (rare earth if possible).
- Use of a grid is essential for all but cats and the smallest of dogs.
- Anaesthesia is a prerequisite for accurate positioning as spinal conditions are painful and the necessary positioning will not otherwise be tolerated.
- Care should be taken with positioning patients with suspected spinal fracture or instability.
- High mAs and low kV will produce a short grey scale and good bone/soft tissue contrast.
- Lateral and ventrodorsal films are essential. Ventrodorsal is preferred to dorsoventral, because it results in the smallest film-object distance (FOD). Oblique views are useful in some situations.

For the lateral recumbency views, foam blocks are placed under the cervical and, if necessary, lumbar spine and under the muzzle. Accurately positioned films require that the whole spine is parallel to the tabletop even if only a small area is under examination. Use foam blocks between the limbs and a foam wedge beneath the sternum to prevent axial rotation. In small dogs/cats, placing a large size cassette underneath the whole patient makes it easier to maintain the whole vertebral column at one level.

The primary beam should be centred over the area of interest (determined from clinical signs and neurological examination). The x-ray beam diverges towards the edges of the collimation and will create image distortion in this

Figure 11: Positioning, collimation and centring of the primary beam for the cervical spine.

area. For this reason, it is important to collimate only over a few vertebral bodies, depending on the size of the patient (**Figures 11**).

Ventrodorsal views at the level of the thoracic and thoracolumbar spine will require higher increase in kV than other areas due to the increased thickness and superimposition of the liver.

Acknowledgements

This paper originally appeared in the Spanish veterinary journal *Consulta de Difusion Veterinaria* and is reproduced with kind permission of the author and publishers.

Further reading

Christensen, E. E., Curry, T. S. and Dowdey, J. E. (1978). An introduction to the physics of diagnostic radiology. 2nd edition. Philadelphia: Lea & Febiger,.

Middleton, D. L. (1993). Radiographic positioning for the spine and skull. *Veterinary Clinics of North America. Small Animal Practice: Diagnostic imaging*. **23(2)**: 253-268.

Morgan, J. P. (1993). Techniques of veterinary radiography. 5th edition. Iowa : Iowa State University Press.

Perry, L. R. (1993). Principles of conventional radiography and fluoroscopy. *Veterinary Clinics of North America. Small Animal Practice: Diagnostic imaging*. **23(2)**: 253-268.

Suter, P. F. and Lord, P. F. (1984). Normal radiographic anatomy and radiographic examination. *In*: P. F. Suter (ed.) *Text atlas of thoracic radiography: thoracic diseases of the dog and cat*. Wettswil, Switzerland. pp 1-45.

Suter, P. F. and Lord, P. F. (1984). Methods of radiographic interpretation, radiographic signs and dynamic factors in the radiographic diagnosis. *In*: P. F. Suter (ed.) *Text atlas of thoracic radiography: thoracic diseases of the dog and cat*. Wettswil, Switzerland. pp 77-126.