Refresher: The machine, processing, film faults etc.- a noddy’s guide

Introduction

Before any discussion a good review of the standard of the x-rays in the practice should be undertaken. Sit down and review your radiographs - divide them into: extremities
- abdomen
- thorax

Take your time and critically review the x-rays - what exactly do you feel that should be improved?
Ask yourself the following questions:

Are you unhappy the the standard of all your x-rays or only a subset?
How old are the film/screens if that is what you are using?
Have you more than one speed of film/screen?
Do you have/use a grid?
Is your darkroom light tight?

It is important to closely examine your protocols and get a full picture of what is happening in the practice.

Generation of X-rays

X-rays are a form of electromagnetic radiation. They are formed by a beam of high speed electrons colliding against a target. This process is very inefficient, and only a 1% of the energy used is transformed into X-rays and 99% is produced as heat. Therefore overheating the x-ray tube is a constant problem when x-raying multiple times in a short period of time.

In order to produce X-rays, two basic components are required:

1. A source of electrons- the CATHODE
A small current is applied through the thin filament of the cathode- this is the mA. The greater the current applied, the more electrons are made available x-ray machines have mas settings. Thus the higher the mas setting the greater the quantity of x-rays produced.

2. A target where accelerated electrons will collide- the ANODE
The electrons from the cathode are accelerated to the anode by an electric potential. The X-ray machine uses kilovoltage control (kV) to measure the potential difference between the cathode(-) and the anode(+). The higher the kV the greater the energy of the X-ray photons and thus more penetrating X-rays. A higher kV will also increase the quantity of the X-rays produced per unit time.
Types of X-ray machines:

- Portable - usually less than 100 mA
- Portable- high frequency
- Mobile - up to 500 mA
- Fixed single phase - up to 1000 mA
- Fixed three phase - up to 1500/2000 mA

Image quality:

The overall quality of the final radiographic image is mainly dependent on three factors: film density, film contrast and image sharpness.

Film density:

The density of the film is the degree of blackening. It is mainly dependent upon the quantity of radiation reaching the screen-film. In small animal practice a constant Film focal distance (FFD ) is practically always used - therefore the factors influencing the quantity of x-rays affecting the film are the mAs and the kV

Film contrast:

Film contrast is the difference of film density between adjacent areas. A radiograph with high contrast will only have black and white areas, while a radiograph with less contrast will contain a larger scale of grey tones. The contrast of any radiographic image depends on the following factors:

- The inherent subject contrast which depends on the effective Atomic number and Specific gravity of body tissues e.g. the thorax has a high inherent subject contrast whereas the abdomen has a low inherent contrast.
- The type of interaction of primary beam the tissue which is mainly dependent on kV.
  
  At low kV <70 kV the photoelectric effect (PE) predominates and therefore contrast is enhanced.

  At high kV>70 kV the compton effect (CE) predominates therefore contrast is much lower
- The amount of Scattered radiation produced, which depends on kV,

  At low kV PE effect predominates and therefore scatter is low with no adverse effect on contrast.
At high kV CE predominates and scatter is greater and more likely to reach the film and result in reduced contrast

- the use of a grid- this will decrease scatter and thus improve contrast
- Good collimation- decreases scatter and this increases contrast
- The choice of screen/film- these can be chosen for high contrast (which have narrow exposure latitude) or for wide exposure latitude(with reduced contrast)
- The manner in which the film has been processed can also affect film contrast. Processing for the wrong length of time or temperature or using exhausted developing solutions will adversely affect the contrast of the radiographic image

**Image sharpness:**

Sharpness is the narrowness of the transition zone between areas of different density. Radiographic unsharpness in addition to resulting in loss of fine detail and therefore should be minimized. There are different causes of unsharpness:

1.- Geometric unsharpness: The focal spot where X-rays are produced is not a focal point as such. X-rays are generated over an area rather than a single point. As you can see in the diagram below, this results in blurring of the margins of structures.

![Focal spot diagram](image)

Geometric unsharpness can be minimized by:

- Decreasing the size of the focal spot. Smaller focal spots produce sharper images, but as the heating is distributed over a smaller area of the target, smaller exposure parameters can be used. When dual focus machines are used, the small focus should be used when high definition is required
• longer FFD. Too short distance results in an unsharp image. However two long film focal distance means that higher exposures are needed. This may result in tube overheating and larger exposure times
• minimise object film distance (OFD) -keep the patient as close to the cassette as possible

2.- Photographic unsharpness:

This results mainly from the size of the AgIBr crystals in film emulsion and the phosphor crystals in the intensifying screen.

-> Use high definition film/screen combinations when detail required- these tend to be slower film screen combinations and require more exposure- Suitable for use on limbs. Faster film screen combinations are used for thorax /abdomen as the exposure can be reduced

3.- Movement unsharpness:
Movement of the X ray tube, patient or film will cause blurring of the radiographic image.

Movement blurring can be controlled by:
Using stable machine stand and table
Using physical or chemical restraint of the patient
Using foam pads, sand bags, ties,... to immobilize patient
Using shorter exposure times

4.- Patient unsharpness.
Patient unsharpness results from either movement or the edge contour of structures and organs

**Reduction of scatter**

The production of scatter and its effects in image quality can be controlled in different ways:
• Decreasing the amount of scatter produced.
• Reducing the amount of scatter reaching the film.
• Reducing the effect of scattered radiation on the film.

1. Limiting the amount of scatter produced
• Use lower kV when possible. When high kV is used, more Compton interactions occur, and therefore more scatter is produced. Also, the scatter will have higher energy and will be more likely to reach the film.
• Collimate the beam: the smaller the volume of irradiated tissue- the less the scatter produced

2. Reducing the amount of scatter reaching the film.
   • Use a grid
   • Lead foil backing in cassette.

3. Reduce the effect of scatter on the film.
   • By using rare earth intensifying screens which are less sensitive to scatter.

Remember that decreasing the amount of scatter produced is also very important from a point of view of radiation safety.

**Use of Grid:**

The purpose of a grid is to reduce the amount of scatter reaching the film and improve radiographic contrast.

The grid consists of multiple lead strips separated by an interspace radio-lucent material. Most of the primary beam passes through the inter-space material whereas a large proportion of the scatter, because it is projected in an oblique direction will be absorbed by the lead.

There is usually an improvement in contrast by a factor of 1.5 - 3.5
**Grid characteristics:**

**Grid ratio:** measure of the efficiency of a grid at removing scatter. It is calculated by dividing the thickness of the grid by the thickness of the interspaces. (Grid Ratio = h/D) This is typically in the range 5:1 - 12:1

**Grid types:**

- Parallel or linear: the lead strips are vertically aligned so that to the edge of the grid there is more beam attenuation
- Focussed grids: This grids accommodate for beam divergence by angling the lead strips progressively towards the edge of the grid. These grids have to be used at a set FFD

Some of the useful primary beam is also absorbed by the grid. When grids are used, the exposure factors have to be increased to compensate for this lose in primary beam intensity. The GRID FACTOR is the amount by which it is necessary to increase the mAs to compensate for the loss of useful primary beam by the use of a grid. Grid factor is
usually between two and three. This means that the radiation needed to obtain an image when a grid is used is generally over twice the radiation when no grid is used.

Advantages of grids:
• Improvement in radiographic contrast.

Disadvantages of using a scatter grid:
• Increase in exposure factors. This will increase the radiation dose, the exposure time and the stress in the equipment
• Grid lines with stationary grid.
• Possibility of film faults due to poor grid alignment.

Common film faults in traditional screen/film processing:

Film too dark:

• Overexposure:
  Too high kV, mA, or exposure time
  Decreased FFD (film focal distance)
  Wrong Film/screen

• Overdevelopment. It may cause film blackening even in areas that are no exposed to radiation. It occurs when the radiograph is developed too long or the developer temperature is too high

• Film fogging:
  See below

Film too pale:

• Underexposure:
  Too low kV, mA or exposure time
  Increased FFD
  Wrong film/screen
  Exposure not adapted to the use of a grid or grid not correctly used (grid cut-off)

• Underdevelopment:
It can be differentiated from underexposure by looking at the background of the image which should be black. If the film is underdeveloped the background appears grey. The most common causes are:

- Temperature too low or development time too short
- Developer exhausted.

**Film fog:**

- Overall:
  - Scatter
  - Wrong processing
  - Old film
  - Wrong safe light
  - Light leakage into the darkroom
  - Chemicals and heat can also cause fogging
- Localised
  - Faulty cassette.
  - Incorrect handling

**Marks on film:**

- White marks:
  - Dust or dirt inside the cassette (between film and screen)
  - Dirt or contrast material on coat, bed, hair,....
  - Fixer splashes on film.
  - Bending or pressure on film before exposure.
- Black marks:
  - Developer splashes on film.
  - Bending or pressure on film after exposure.
  - Static discharge.
  - Cassette leakage

**Uneven background density**

- Poorly mixed solutions.
- Exhausted developer

**Yellow staining**

- Old developer
- Poor washing
Double exposure

Poor positioning:
• Try and ensure that all major body plane(s) are parallel to film.
• Prevent rotation unless special view.
• Maintain object to film distance low.

Grid faults:
• Poor centering of focussed grids (also called grid cut-off). It results in underexposure
• Reversed focussed grid. The film is underexposed in the periphery of the film.
• Wrong FFD. Focussed grids should be used with a specific FFD

Making an Exposure Technique Chart

A few guidelines

1. Standardise the variables
   Line voltage
   Speed of film/screen combination
   FFD
   Processing factors
   Use of grid

2. Take Trial exposures-eg. abdomen
   Medium sized dog- ok body condition +grid
   Measure the thickness of the tissue
   Select kV and mAs eg. 65kv and then 1,2,4mAs
   Process the film with standardised protocols
   Too dark ~Reduce kV 10 or half mAs
   Too pale ~ increase kV or double the mAs
   Good exposure add to your chart
3. General rules
   
   - <80 kV ~add 2kV/cm increase in thickness
   - 80-100 kV ~add 3kV/cm tissue
   - Double mAs for obese or heavy muscled patients
   - Double mAs for dry P.O.P. quadruple for wet
   - Halve mAs for thorax or immature dog/cat
   - Increase exposures 5-10 kV for contrast or vertebral/spine/skull studies
   - If using a grid ~ increase mAs according to the grid factor e.g. 8:1 grid ratio then treble
     the mAs
   - Remember quadruple the mAs if you double the FFD