Veterinary Radiology Safety
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Eliminate, Isolate, Minimize is the mantra of the New Zealand Department of Labour, Health, and Safety but how do these three words apply to radiology safety?

**Eliminate** - Consider whether the job can be done without exposing staff to the hazard. *Is this film necessary?*

**Isolate** - If elimination is not possible then measures must be in place to isolate people from the hazard. *Can this film be taken using sedation and the use of positioning aids?*

**Minimize** - If elimination or isolation is not possible steps should be taken to minimize the likelihood of harm. *Are protective gowns, gloves, and thyroid shields available and in good condition?*

According to the Webster’s Dictionary safety is defined as, “the condition of being safe from undergoing or causing hurt, injury, or loss.” Along with understanding your rights and responsibilities under New Zealand legislation, as employees it is up to us to take every reasonable step to ensure our safety in the work place. As practicing veterinary nurses we have the added responsibility of ensuring the safety of others.

A basic understanding of the units of measure used to monitor your radiation exposure, and ways to minimize the risks you will encounter in and around radiographic equipment help to ensure that we have a long and healthy career.

**Personal Protective Equipment**

There are several types of personal protective equipment that we use in radiography. In the radiography suite; dosimeters for monitoring exposure, leaded garments, and heavy rubber gloves. In the darkroom; a rubberized apron, a respirator and eye protection.

Dosimeters - Dosimeters are used to measure the user’s exposure to ionizing radiation. The most commonly used type, film badge dosimeters (FBD), contain at least two layers of film that after exposure are removed and developed. Just like radiographs, areas of high exposure develop dark.

Dosimeters are sent in at regular intervals, from one to three months, to the National Radiation Laboratory (NRL) for development and interpretation. An official report detailing the type and amount of radiation exposure is then returned to the clinic and must be made available for review by all employees. Badges are staff, and site-specific. Badges should not be shared between employees, and if you work at more than one hospital you should be provided with a badge for each location so that exposure levels can be monitored accurately.

Badge dosimeters are worn on the collar, mid-torso, or waist underneath leaded garments to measure the amount of exposure the user received. Where these monitors are to be worn on the body will be outlined in the practice’s Radiation Safety Plan. Prolonged exposure to heat, such as running the badge through a clothes dryer, or leaving it in the car on a warm day, can affect dosimeter readings. They should be stored away from direct sunlight, in a cool location outside of the radiology room.

Leaded garments – Lead is a noxious toxin which causes harmful effects in humans. Why then do we wear it as protection? Although they are commonly called lead gowns, strictly speaking they don’t contain lead. Protective clothing often only contains a small amount of
lead along with other non-toxic metals such as tin, and barium. These metals are mixed with rubber and other flexible materials and sandwiched between thin sheets of urethane-coated nylon fabric to protect the wearer. Differences in the amounts of metals and rubber in the mix affects the garments flexibility, weight, expected life, and cost.

Gowns and thyroid shields with a lead equivalence of 0.25mm, a variety of gloves with a lead equivalence of twice that of gowns at 0.5mm are all necessary protection. These garments protect areas of the body that are most susceptible to radiation damage such as the thyroid, and reproductive organs. Lead glasses can also be used.

No part of your body should ever be in the primary beam. If your hands are in the primary beam, even if they're covered with lead gloves, you are receiving radiation. Scatter radiation comes at you from all angles so using gloves to cover your hands does not protect them from scatter bouncing off the table. Figure 1 clearly shows the image of a radiographer’s glasses and nose as she leaned in to the primary beam, allowing the radiation to pass between her eyes and glasses.

Personal Protective Equipment for the Darkroom

Note:  PPE used in the darkroom does not provide protection against radiation. It is designed to protect against chemical exposure.

Rubber gloves – Because of the extremes of pH encountered in radiographic chemicals it is necessary to use heavy rubber gloves which will protect the wearer from chemical contact. Exam gloves are not sufficient for this task as they are not high enough to protect the wrists and arms of the wearer, and may be degraded by prolonged exposure to chemicals.

After use, gloves should be washed with pH neutral soap and hung up to dry.

Rubberized apron – A rubberized apron will help protect the wearer from splashes and inadvertent contact with chemicals that may occur when leaving mixing chemicals or leaning over processing tanks. The liquid impermeable gowns used in surgery are not designed to tolerate chemical contact and may not protect the wearer.

Respirator – “To protect against Glutaraldehyde fume inhalation, a half-face respirator with appropriate organic vapour cartridges would be the least degree of protection required, and individual face fit would need to be achieved.”

Eye protection – Glasses are not enough to protect you from chemical splash. Safety goggles which provide protection to not just the front of your eyes, but the top, bottom and sides should be used.

When mixing chemicals, remember to pour the chemical in to the water, and not the water in to the chemical, this is to ensure that it is primarily water that will splash.

Units of Measure

2 Author’s Note: I have seen photographs of bones visible after being radiographed through lead garments, but was unable to recreate this effect using a skeletal polar bear foot and rare earth cassette on the table top at an exposure equivalent for radiographs of a 17cm pelvis (kVp 69, MA 300, time 0.16)
3 Health and Technical Services, Occupational Safety and Health Service, Department of Labour, The Safe Occupational Use of Glutaraldehyde in the Health Industries, August 1992
Different types of radiation (Gamma rays, Alpha and Beta particles, X-Rays, etc.) are not equally harmful so radiation is measured in a large variety of units depending on the type of radiation they’re measuring and how it is absorbed by the body. The type of dosimeter that is used is dictated by the type of radiation exposure you’re receiving. To come up with an average measure we refer to an “equivalent dose”. Different structures in the body have varying sensitivity to radiation. The term “equivalent dose” is used when referring to the radiation risk averaged over the entire body. This equivalent dose is measured in sieverts (Sv). A sievert is the amount of absorbed radiation divided by how much energy is released by a specific type of radiation. That all sounds, and is, very complicated for those of us who aren’t physicists.

In New Zealand the Sievert (Sv) or milliSievert (mSv – one thousandth of a sievert) is the most commonly used measure. In other parts of the world the rem (roentgen equivalent man) is used. One-hundred rem is equal to one Sv.

**Maximum Safe Dose**

As discussed in the Radiation Legislation article much of our yearly exposure comes from naturally occurring sources or items commonly encountered in our everyday lives such as luminous watch dials, and airline flights.

The worldwide average background dose is about 2.4 millisievert (mSv) per year. This varies widely depending on the altitude, and how Uranium rich the soil is. Americans living around Denver, Colorado are exposed to levels as high as 10 mSv per year with no adverse effects shown at that level. If you were to receive a standard chest radiograph you would receive about 0.1 mSv which is equivalent to about 10 days of background radiation. A computer tomography (CT) scan of the abdomen is equivalent to around 10 mSv or 3 years of background exposure.

Radiation affects everyone differently so it is difficult to predict what dose is considered harmful. Based on data from the survivors of the August 1945 atomic bombing of Hiroshima and Nagasaki, Japan, it is believed that 50% of the population would die within thirty days after receiving a dose between 3500 – 5000 mSv.

<table>
<thead>
<tr>
<th>Some examples of the effects of acute exposure to large doses of radiation</th>
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<tr>
<td>10 Sv dose - Risk of death within days or weeks</td>
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<tr>
<td>1 Sv dose - Risk of cancer later in life (5 in 100)</td>
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<tr>
<td>50 mSv - Annual dose for radiation workers in any one year</td>
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The goal of any radiology safety protocol is to decrease the possibility of acute exposure, and keep chronic exposure “as low as reasonably achievable” (ALARA) so we need to be concerned with levels far lower than those that cause death.

The radiation exposure limits from all sources outlined by most international organizations is 50 mSv per year. Taking in to consideration that 80% of our yearly exposure comes from sources outside the veterinary hospital, leaves an exposure limit of 10 mSv per year. In an average small animal practice in New Zealand vet nurses receive doses around <0.05 mSv per

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4 0.003 – 0.01 mSv/hour (0.3 – 0.97 mrem/hour)

5 USNRC, Fact Sheet, Biological Effects of Radiation, 2004

month on a trunk dosimeter. Vet nurses working in a specialty radiology department may receive around 0.6 mSv per month for an extremity dosimeter. Both of these measures are well within the specified limits.

Below is an exposure guideline chart put together by the National Radiation Laboratory. It is worth noting that women who are pregnant, or trying to get pregnant, should receive no more than one-quarter of the listed dose.

| Dosimeter reading safety guidelines as outlined by the National Radiation Laboratory (NRL) |
| Collar dosimeters – 3.0 mSv per month |
| Extremity dosimeters – 9.0 mSv per month |
| Trunk dosimeters – 1.0 mSv per month |

Safety Basics

Just as all health and safety considerations, safety around the radiology suite can be summed up in three words; **Time, Distance, Shielding**.

- Reduce the amount of time you spend taking radiographs by rotating staff. Take radiographs that use the minimal exposure time necessary to get a diagnostic radiograph.

- Keep all of your bits as far away from the beam, and scatter as possible. Radiation that masses through a greater mass (e.g. abdomen vs. foreleg) will result in more radiation being absorbed by the object being imaged and will result in less scatter provided appropriate collimation is used.

- Wear protective equipment, get out of the room if possible, and utilize free-standing lead screens.

General Hazards

Many of the hazards associated with producing radiographs have nothing to do with radiation. Slips, trips and falls are common, but the chemicals used in processing radiographs commonly cause health concerns that worsen over time.

Worldwide, one of the first reported cases of the toxic effects of processing chemicals was Marjorie Gordon, a radiographer from Otaki. Marjorie had been a radiographer for more than twenty years when her clinic changed over to an automatic processor. To compensate for the shortened developing time automatic processors run at much higher temperatures than manual dip tanks (32C vs. 15 – 24C for manual). With natural evaporation associated with higher temperatures more fumes are produced. There was no external exhaust fan installed because at the time there was no understanding that chemical fumes could cause long-term health problems. Marjorie's symptoms ranged from ringing in the ears to generalized weakness due to heart arrhythmias. When she took time off work her symptoms would improve and each time she returned to work her symptoms became worse than they were before she left.

Marjorie became a crusader for chemical safety and thanks to her persistence and research the harmful effects of exposure to darkroom chemicals is now universally understood.

Chemical sensitivity varies from person to person so even under adverse conditions not everyone may become ill, while others may have serious health problems from relatively low
exposure. The body tends to become sensitized to chemical exposure so that with every exposure symptoms can become worse over time. There is also a cross-over effect that although a person might only be sensitized to one chemical the immune system becomes overwhelmed and sensitivities to other chemicals may develop.

The Department of Health wrote to hospitals in New Zealand in July 1985 that, “developers and fumes may cause a variety of health problems”, but that “good ventilation and observation of good hygiene protocols will, in most cases, minimise the occupational health hazard”.

**Processing Chemicals**

Below is a list of some of the chemicals contained in the radiograph developer and fix solutions. Some of these chemicals, like Glutaraldehyde are being phased out because of their level of toxicity.

Glutaraldehyde – " In the health sector, Glutaraldehyde has two principal uses; as a hardening agent in x-ray film developing processes and as a cold high-level disinfectant." Glutaraldehyde has also found use as a tissue fixative; a biocide in air conditioning plants; a chemical intermediate; an ingredient in embalming fluid; a fabric softener and a tanning agent.

It is estimated that 20–30% of embalming in New Zealand now uses Glutaraldehyde. In the agricultural sector, Glutaraldehyde is used as a disinfectant for animal and plant. In November 1984, the New Zealand Department of Health wrote to the chief executives of all hospital boards in the country referring to a Massey University study that had identified risks associated with the use of photographic development chemicals under unsatisfactory work conditions. Glutaraldehyde was identified as the most likely chemical implicated. This sentiment was again highlighted in 2005 when the Canadian Centre for Occupational Health and Safety named Glutaraldehyde as the number one cause of occupational respiratory illness in health care workers.

Chemicals containing alternatives to Glutaraldehyde are available on the market and should be used whenever possible.

Acetic acid (CH$_3$COOH) – Not all uses of acetic acid are sinister as it can also be found in 5 – 8% concentrations of vinegar. In higher concentrations it is combustible, corrosive, and is a strong irritant to skin, eyes, lung tissue and teeth. It can cause symptoms of irritation to eyes, skin, nose, throat, chemical burns, skin sensitization, dental erosion, hyperkeratosis, and respiratory problems.

Sulphur dioxide (SO$_2$) – Like Acetic Acid, not all levels of Sulphur dioxide exposure are harmful. It is an important compound in wine making, has antimicrobial properties, and can be used as a preservative for fruit. Before the use of Freon it was used as a refrigerant.

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8 Health and Technical Services, Occupational Safety and Health Service, Department of Labour, *The Safe Occupational Use of Glutaraldehyde in the Health Industries*, August 1992

9 [http://www.cdc.gov/niosh/npg/npgd0002.html](http://www.cdc.gov/niosh/npg/npgd0002.html)

When it reaches high levels Sulphur Dioxide becomes a concern. It is found during volcanic eruptions, and affects the lungs, can cause chemical burns of the nose and throat, respiratory difficulties, and severe airway obstructions.

Hydroquinone (C₆H₄(OH)₂) – Available as a 2% topical solution for skin whitening until 2006 when Hydroquinone was banned for sale by the United States Food and Drug Administration (USFDA) over concerns about high rates of thyroid, and renal tumours as well as leukaemia among users. It is a strong skin irritant and poisonous if digested. It occurs naturally in the leaves, bark and fruit of a number of plants such as cranberry, and blueberry bushes.

Hydroquinone is light and air sensitive and must be stored in a dark cool environment. Special care should be taken with its disposal and it is toxic to aquatic organisms and may cause long-term damage to the environment.

All of these chemicals can pose minimal risk if stored and used appropriately, following OSH guidelines for use of PPE and air-exchange within the darkroom. "Changes in usage in veterinary practice have reflected those in hospitals, with alternative chemicals being used in both x-ray processing and high-level disinfection."¹¹

Of course, with the slow introduction of digital radiography the use of film developing chemicals and the associated risks will become a thing of the past.

**Hazardous Spill Clean Up**

If there is liquid on the floor when you go into the darkroom **turn on the exhaust fan** and immediately put a danger, chemical spill sign up until you can determine what the spill is and clean it up. Put on rubberized gloves, respirator, eye wear and long-sleeved rubberized gown. If you have an automatic processor, switch it off.

**To determine what the spill is:**
- Contain and mark the spill by putting rolled up towels around the area.
- Turn the white light out and turn the red light on.
- Remove an x-ray film and place the film in the spill
- After one minute remove the film with tongs.
  - If the liquid is developer the film will go black.
  - If the liquid is water, it will not change and the liquid can simply be mopped up.
  - If the liquid is fixer it will go clear.

After you have determined what the spill is attempt to locate the source of the leak. The darkroom may have to be closed off until the processor servicing company is able to come out and attend to the leak.

If it is determined that the spill is either developer or fixer follow these guidelines:

1) Pour cat litter liberally over the spill and leave it to absorb as much liquid as possible.
2) Sweep cat litter in to a dust pan and dispose of it in a hazardous waste bag.
3) Mop the remaining liquid up with towels. All towels will be disposed of in hazardous waste according to hospital protocol.¹²

¹²Towels should not be laundered as this increases the chances of chemical contact, fume inhalation, and corrosion damage to the clinic’s laundry facilities.
4) The floor should be mopped as usual with hot water. Ensure that no other chemicals or
   cleaning products are present in the mop water as this can result in the production of toxic
gas from mixing chemicals.
5) Thoroughly rinse the broom and dust pan with running water.
6) The room should be aired out until no chemical odour is detected.  

First Aid for Chemical Exposure

First, avoid exposure to chemicals whenever possible, and as previously discussed used
rubberized PPE, full-coverage eye protection, and a respirator to avoid all possible contact. A
few other items should be available in the radiology darkroom area.

pH neutral soap – Skin pH varies across the body surface, but averages at 5.5. Most
commercially available cleansers are at a pH of 9.5 to 10.5. Skin should be rinsed
immediately with copious amounts of water and washed with a pH neutral soap to help
restore your skin's natural balance in the event of inadvertent contact.

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<tr>
<th>Test Method</th>
<th>Developing solution pH</th>
<th>Fix solution pH</th>
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<tbody>
<tr>
<td>Whatman pH test strips</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Shindengen Isfet pH meter</td>
<td>12.5</td>
<td>4.7</td>
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</tbody>
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Eye wash station – an eyewash station connected directly to the fresh water supply should be
available. In the event of accidental contact eyes should be rinsed under cool running water
(it is best to have the hot water disconnected from the faucet where the eye wash station is
connected) according to MSDS instructions.

Material Safety Data Sheets (MSDS) – You should be able to find MSDS information within
the first 30 seconds after exposure. The best way to do this in the darkroom is to have
abbreviated sheets typed up and posted in an obvious place for quick reference.

Conclusion

Although there are many potential hazards in and around the radiology suite, with knowledge,
planning, and the use of the appropriate equipment hazards can be:

Eliminated by taking only the necessary images, and ensuring the appropriate amount of air-
exchange in your darkroom. Take the time to measure, and carefully set your machine to
achieve the best possible results with the minimum amount of shots.

Isolated by employing measures such as sedation, the use of positioning devices, and
maximum distance from the primary beam.

Minimized by the proper use of protective gowns, gloves, thyroid shields and appropriate
PPE in the handling of chemicals.

Acknowledgements

Peer reviewed by: Charleen Romine, Radiology Supervisor, University of Georgia
Veterinary Teaching Hospital, USA.

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