DRAFT FOREWORD

[[To be added: IAEA programmatic context, purpose of the work, collaboration, etc.]]

This Safety Report on Radiation Protection and Safety in Veterinary Medicine provides guidance on fulfilling the requirements of GSR Part 3 with respect to veterinary uses of ionizing radiation.

Ionizing radiation is used in veterinary practice for diagnosis and therapy. A systematic approach is applied to ensure that there is a balance between benefits from the veterinary use of ionizing radiation and risks associated with radiation exposure of workers, members of the public and animals.

Unlike in human medicine, for which radiation practice is limited to medical facilities, veterinary use of ionizing radiation can also take place outside of a dedicated facility. This poses specific problems and necessitates specific education and training for the veterinary practitioner. In many situations animal handling involves the presence of additional individuals (animal handlers) in the room during procedures, and this necessitates additional protective measures.

The increasing public demand for best practice animal care necessitates the use of more advanced imaging and therapy equipment, which will result in the installation of advanced equipment in more facilities. At the same time the availability of the necessary expertise to select, perform and interpret imaging studies needs to increase. Currently, there is a worldwide shortage of suitably trained individuals.
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1. INTRODUCTION

1.1. BACKGROUND

The Fundamental Safety Principles [1] establish the fundamental safety objective and the principles of protection and safety. Requirements designed to achieve this objective and to apply these principles are established in Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (GSR Part 3) [2].

This Safety Report on Radiation Protection and Safety in Veterinary Medicine provides guidance on fulfilling the requirements of GSR Part 3 [2] with respect to veterinary uses of ionizing radiation. It is assumed in this Safety Report that the individual State has an effective governmental, legal and regulatory infrastructure for radiation safety that covers veterinary uses of ionizing radiation, or otherwise that it is able to develop such an infrastructure.

Ionizing radiation is used in veterinary practice for diagnosis and therapy. Ionizing radiation can cause harmful effects on people and the environment. Radiation protection and safety is necessary because there is no absolutely safe level of exposure to ionizing radiation. Exposure may also pass unnoticed owing to the lack of physical sensation and the delay in the onset of some tissue damaging effects.

A systematic approach is taken to ensure that there is a balance between the benefits from the veterinary uses of ionizing radiation and the risks associated with radiation exposure of workers and members of the public, and of animals.

Veterinary practitioners may be considered to have a moral obligation to provide veterinary assistance and care to animals. Unlike in human medicine, where medical practice using radiation is limited to medical facilities, veterinary uses of ionizing radiation can take place outside of dedicated facilities.

This poses specific problems and necessitates specific education and training for the veterinary practitioner. In many situations animal handling involves the presence of additional individuals (animal handlers) in the room during procedures, and this necessitates additional protective measures.

Radiation modalities in imaging and therapy will continue to evolve over the coming years, and veterinary medicine will continue to follow closely what becomes available in human medicine. Newer and more complex radiation technologies may lead to new measures.
for radiation protection and new building designs, whereas the principles of radiation protection and safety remain unchanged.

Animal owners in developed countries will increasingly have access to the latest techniques (computed tomography scans, scintigraphy scans and positron emission tomography) scans, as well as radiotherapy). An increasing number of centres will be offering these modalities. Veterinary medicine for companion animals is a service industry, driven mainly by the animal owners’ demand for diagnostics and treatments.

The rise of veterinary medical insurance in some countries plays a major part in the progress of veterinary medicine by making advanced diagnostics and treatments more affordable for pet owners. As more veterinary clinics install expensive imaging equipment, there may be a temptation to offer and to perform diagnostics modalities more readily, sometimes with questionable veterinary benefit. The lack of available scientific evidence in some cases may complicate the decision making process.

Besides the ethical concerns associated with this situation, the performance of unnecessary or inappropriate diagnostic modalities leads to radiation exposure for workers that could be avoided. Prevention of disease is considered part of human health care. Pre-purchase radiographs of horses are an example where ionising radiation used without a veterinary indication, but for screening to assess the likelihood of future veterinary needs.

With the horse’s role changing from a working to a leisure animal this practice will increase in demand. Similar examples of radiographic surveys also exist in small animals in the context of breed selection (e.g. hip dysplasia) or routine check-ups (e.g. thoracic and abdominal radiographs in geriatric patients).

In developing countries where veterinary medicine has remained limited to production animals until now, the number of companion animals is increasing and some pet owners are also seeking for the best available diagnostic and treatment.

As the demand for veterinary medicine rises, the standard of animal care increases. This involves the use of more advanced diagnostic and therapeutic techniques. The availability and maintenance of suitably serviced equipment and safe operation of the equipment rely on suitably trained individuals for all aspects.

Hybrid imaging is now widely available in human medicine, whereas it lags behind in veterinary medicine, mainly owing to financial restrictions. However, within some years prices will fall, and/or second-hand equipment will become available and more affordable for
veterinary facilities. In the meantime, hybrid imaging techniques for animals are mainly used for research purposes where access permits it. Radiation protection issues are similar to those described earlier, with the difference that specific issues relating to both techniques in hybrid imaging have to be considered.

Recent developments in novel radionuclide therapies in human medicine give rise to possibilities for their use on animals. Radiation protection issues will largely depend on the route of elimination from the animal and the half-life and effective half-life of the radionuclides used. Specific radionuclides might necessitate specific additional precautions and authorities.

Radiotherapy treatment of animals in many countries is likely to be performed in radiotherapy facilities for humans, where permitted. It may otherwise be performed with the use of superficial or orthovoltage (kV) units, for which the requirements for radiological protection are easier to meet.

Cobalt-60 megavoltage units may also be used in some countries. There is a need for shielding and for radiological procedures to be adapted for megavoltage radiation units, but this technique benefits from having few maintenance constraints. However, servicing of these units will probably become less available with time. All aspects of disposal and replacement of the radioactive sources have to be considered.

Newer techniques include intensity modulated radiotherapy, image guided radiotherapy and stereotactic radiosurgery techniques. These techniques are typically associated with machines with higher dose rates and with a large number of monitor units to be delivered per treatment. Higher energy machines (>10 MV) will also be used more commonly.

The use of higher energy types of equipment and delivery techniques necessitates more radiation shielding, including more shielding against neutrons. If a veterinary radiation facility is having a lower energy machine replaced by equipment of higher performance, the existing building would have to be adapted to provide proper shielding for the higher energy equipment and its associated techniques.

The increasing public demand for best practice animal care necessitates the use of more advanced imaging and therapy equipment. This will result in the installation of advanced equipment in more facilities. At the same time, the availability of the necessary expertise to select, perform and interpret imaging studies needs to increase. Currently, there is a shortage of suitably trained individuals.
1.2. OBJECTIVE

The objective of this Safety Report is to provide guidance to licensees and to practitioners in veterinary facilities on the development of an effective radiation safety programme. Guidance is also given on the design of facilities for the provision of diagnostic imaging using X rays, nuclear medicine procedures and radiotherapy services in veterinary medicine.

This guidance is designed to achieve the objectives of radiation protection in the imaging and treatment of animals. It is not intended to preclude alternative methods of achieving the objectives of radiation protection. The imaging and treatment of animals poses specific challenges depending on the nature of the animal. Guidance on radiation safety needs to be considered together with safety in handling animals and the safety of the animals themselves.

1.3. SCOPE

This Safety Report provides information and guidance for ensuring protection and safety for workers and the public in relation to exposure due to sources of ionizing radiation used in veterinary medicine. It covers veterinary radiological procedures in diagnostic radiology using X rays, image guided interventional procedures, nuclear medicine, and radiation therapy.

The guidance includes measures for the optimization of protection and safety for workers and public, and measures to optimize the exposure of animals in veterinary radiological procedures.

Veterinary use of ionizing radiation is a planned operation and the requirements of Sections 2 and 3 of GSR Part 3 [2] apply, as appropriate. Veterinary use of ionizing radiation involves different categories of exposure: occupational exposure of those involved in carrying out radiological procedures and of other workers (e.g. in stables and on farms), and public exposure of members of the public, such as animal owners and other people assisting with animals, and people in waiting rooms and in holding areas for animals.

This Safety Report does not include guidance on the exposure of animals to ionizing radiation for purposes other than diagnosis and treatment.

1.4. STRUCTURE

Section 2 gives general guidance on radiation safety in veterinary medicine. This relates to the requirements for radiation protection, the graded approach, roles and responsibilities, and education and training.
Sections 3–5 give guidance on radiation protection and safety in specific areas of the use of ionizing radiation in veterinary medicine: Section 3 on veterinary diagnostic radiology using X rays, Section 4 on veterinary use of unsealed sources, and Section 5 on veterinary radiation therapy.

2. GENERAL GUIDANCE ON RADIATION SAFETY IN VETERINARY MEDICINE

2.1. GENERAL

Modern veterinary practice includes the use of ionizing radiation in diagnostic radiology, nuclear medicine and radiation therapy. Rapid advances in technology provide more sophisticated approaches to imaging and therapy.

Veterinary use of ionizing radiation takes place in a variety of settings, including veterinary clinics and locations outside of veterinary facilities, such as at stables and farms.

In veterinary medicine, members of the public, including animal owners and other people assisting with animals, may be affected by the radiological procedures, and this gives rise to safety considerations. Other considerations arise from the variety of species and breeds, and sizes and temperaments, of animals in veterinary medicine.

2.2. APPLICATION OF THE REQUIREMENTS FOR RADIATION PROTECTION

2.2.1. Justification

Justification of exposure to ionizing radiation is common to all types of radiological procedures of veterinary medicine. The requirement for justification states that no practice involving exposure to radiation is to be adopted unless it produces sufficient benefit to the exposed animal (and indirectly to workers and the public) to offset the radiation detriment that it causes [2]. All veterinary radiological procedures need to be justified before a procedure involving exposure to ionizing radiation can be commenced.

In the justification process in veterinary medicine, occupational exposure, public exposure and exposure of the animal need to be considered. The radiation detriment from the exposure of the staff of the veterinary facility and of the public therefore needs to be taken into account. The veterinarian needs to consider several issues in relation to the exposure of the animal in making the decision on justification.
The animal has the legal status of being the property of its owner. Owners will request procedures to protect the value of their property. The nature of the relationship between the owner and the animal also needs to be considered. This can be an economic relationship, as with racehorses or farm animals.

Animals are also owned for companionship, whereby the animal’s value is in its significance to the owner, such as for pets such as cats and dogs.

Finally, the veterinarian also needs to consider the welfare of the animal, and there will be cases where the welfare of the animal conflicts with the owner’s wishes [3].

2.2.2. **Optimization of protection and safety**

The optimization of protection and safety, when applied to the exposure of workers and members of the public, is a process for ensuring that the likelihood and magnitude of exposures and the number of individuals exposed are as low as reasonably achievable, with economic, societal and environmental factors taken into account. This means that the level of protection would be the best possible under the prevailing circumstances (Ref. [2], para. 1.15).

Dose constraints are used, at the planning stage, for optimization of protection and safety. Dose constraints are applicable for occupational exposure and for public exposure in the veterinary uses of ionizing radiation. The premise of a dose constraint is to place an upper value on individual doses that may be received from exposure due to a source, a set of sources in a facility, a practice, a task or a group of operations in veterinary medicine. This upper value on individual doses represents what could be considered acceptable in the process of optimization of protection for those sources, practices or tasks (Ref. [2], paras 1.22–1.23, 1.25–1.26, 1.28, 3.25).

Depending on the situation, the constraint can be expressed as a single dose or as a dose over a given period. Since veterinary staff often perform different services, the use of dose constraints is necessary to ensure that the dose limits are observed if workers incur exposures due to different sources or tasks.

The dose constraint for each particular source of radiation exposure is intended, among other things, to ensure that the sum of doses from planned operations for all sources under control remains within the respective dose limits. Dose constraints are not dose limits; the exceeding of a dose constraint does not represent non-compliance with regulatory requirements, but it might result in follow-up actions.
The three factors relevant to dose reduction (time, distance and shielding) need to be combined in the design of buildings and rooms for veterinary facilities, in the design of radiological equipment, and in the local rules and procedures, to optimize radiation protection for occupational exposures and public exposures.

Occupational exposure and public exposure can be reduced by one or more of the following means:

1. Minimize the exposure time of the worker or the member of the public to the source (decreased exposure time = decreased exposure);
2. Maximize distance between the worker or the member of the public and the source (increased distance = decreased exposure);
3. Use appropriate shielding between the worker and the member of the public (increased shielding = decreased exposure).

2.2.3. Dose limits

The requirements for dose limits are that dose limits apply for occupational exposure and public exposure of individuals in planned operations. Dose limits for workers and dose limits for members of the public have been established in GSR Part 3 [2] and are presented in Table 1. GSR Part 3 takes into account the latest recommendations of the International Commission on Radiological Protection [4].

Although the dose limits in Table 1 are maximum permitted values, all doses are to be kept as low as reasonably achievable [2].

---

1 The exposure of workers and members of the public can be further reduced by the use of standard operating procedures and the use of positioning devices and animal restraints (such as manual restraints, sedation or general anaesthesia). (See Sections 3, 4 and 5 for further guidance.)
TABLE 1. LIMITS ON THE ANNUAL EQUIVALENT DOSE (DOSE LIMITS) FOR OCCUPATIONAL EXPOSURE AND PUBLIC EXPOSURE IN PLANNED EXPOSURE SITUATIONS (SEE REF. [2], SCHEDULE III)

<table>
<thead>
<tr>
<th>Applicable body organ or tissue</th>
<th>Occupational exposure (workers) (mSv)</th>
<th>Occupational exposure (apprentices and students, age 16–18 years) (mSv)</th>
<th>Public exposure (members of the public) (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
<td>50/20</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Lens of the eye</td>
<td>50/20</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Hands and feet or skin</td>
<td>500</td>
<td>150</td>
<td>50</td>
</tr>
</tbody>
</table>

2.3. USE OF THE GRADED APPROACH

The ‘graded approach’ is a concept that underpins application of the system for protection and safety. GSR Part 3 states that the “application of the requirements for the system of protection and safety shall be commensurate with the radiation risks associated with the exposure situation” (Ref. [2], para. 2.12).

GSR Part 3 places responsibilities in respect of a graded approach on each of the government, the regulatory body, registrants and licensees, and employers. The government and the regulatory body use the graded approach in setting and enforcing regulatory requirements. For example, it would be expected that regulatory bodies would devote fewer resources to regulating a veterinary practice owning a single conventional X ray unit for radiology than to regulating a veterinary practice carrying out radiation therapy procedures or image guided interventional procedures.

Registrants or licensees and employers use the graded approach in the measures that they take for protection and safety. For example, in order to meet the requirements of GSR Part 3 [2], the registrant or licensee of a veterinary practice owning a single conventional X ray unit would not be required to implement as comprehensive a quality assurance programme as would be required for a veterinary practice owning a radiation therapy facility.

The occupational exposure associated with veterinary uses of ionizing radiation varies significantly, depending on the radiological procedure. For example, in radiology, levels of risk associated with occupational exposure in dental radiography are considered to be relatively low, whereas the levels of risk for image guided interventional procedures are considered relatively high in comparison.
2.4. ROLES AND RESPONSIBILITIES

2.4.1. Government

2.4.1.1. General

The roles and responsibilities of governments with regard to radiation protection and safety are set out in requirements of GSR Part 3 [2], with further requirements established in Governmental, Legal and Regulatory Framework for Safety (GSR Part 1) [5].

These responsibilities for radiation protection and safety include:

(a) Establishing an effective legal and regulatory framework for protection and safety for different exposure situations;
(b) Establishing legislation to meet specified requirements;
(c) Establishing the regulatory body as an independent body with the necessary legal authority, competence and resources;
(d) Establishing requirements for education and training in radiation protection and safety;
(e) Ensuring that requirements are established for the formal recognition of qualified experts, such as veterinary professionals;
(f) Ensuring that arrangements are in place for:
   - The provision of technical services (including radiation monitoring services and standard dosimetry laboratories);
   - Educational and training services.

All these responsibilities are relevant to the safe use of ionizing radiation in veterinary medicine.

Formal recognition of veterinary professionals is a means of ensuring that only individuals with the appropriate competences are allowed to assume specific roles and responsibilities. For the veterinary use of ionizing radiation, this applies in particular to individuals assuming the role of veterinary practitioner or veterinary technologist.

2.4.1.2. The government or the regulatory body

Other organizations that contribute to radiation protection and safety in the veterinary use of ionizing radiation include technical standards associations, regulatory agencies for
radiation devices and agencies for the assessment of health technologies. Such organizations issue standards or reports that could have direct implications for radiation safety.

In countries with such relevant organizations, the government or regulatory body is encouraged to foster cooperation between all bodies that can contribute to radiation protection. In countries without such organizations, it is advisable that the government or regulatory body considers adopting or adapting relevant policies from relevant organizations in other countries.

2.4.2. The regulatory body

The regulatory body for radiation protection fulfils regulatory functions such as: establishing regulatory requirements and guidelines; review and assessment of applications for authorization; authorization and inspection of facilities and activities; and enforcement of legislative and regulatory provisions.

A prerequisite for effective performance of the regulatory body is the employment of staff with appropriate expertise. The regulatory controls enforced by the staff need to be applied knowledgeably, and not just as an administrative exercise [2].

Regulatory bodies determine the form of authorization needed, specifically registration or licensing. Registration is advised for diagnostic imaging facilities that do not perform interventional procedures. Licensing is advised for other, more complex types of practice.

In order to grant an authorization, the regulatory body would usually base its decision on written documentation provided by the operator of the veterinary facility that is applying for authorization. The level of complexity necessary in the documentation will depend on the complexity of practices performed in that facility.

During the review of the application for authorization, the regulatory body needs to check the level of education and training for the different parties involved in the radiological procedures. These include the veterinarian, the veterinary assistant, the radiation protection officer and the qualified expert.

It is advisable for the regulatory body recognize the qualifications of key persons in radiation protection in veterinary medicine, such as the veterinarian and the qualified expert in radiation protection. For this purpose, the regulatory body usually sets up a set of specific requirements for such qualifications.
The regulatory body will also review the safety measures foreseen, the design of shielding, the plans, the management system, the safety assessment for the sources of radiation to be authorized, and the quality assurance programmes.

The regulatory body may decide to perform an on-site inspection before granting the authorization. The duration of the authorization is decided in accordance with the complexity of the procedures performed.

It is advisable for the regulatory body to perform periodic inspections of veterinary facilities in order to check whether the registrant or licensee or the responsible veterinarian is complying with the rules and regulations. The frequency of such inspections is usually based on the complexity of the particular use of ionizing radiation and the associated risks.

It is considered a good practice for the regulatory body to provide licensees with clear acceptance criteria for all types of veterinary equipment, including the minimal frequency of retesting of this equipment. This ensures that the equipment used is considered safe for the people involved and also for the animals. This is especially necessary in the case of second hand equipment.

The regulatory body can also choose to set dose constraints for particular situations, in order to ensure that the requirements for optimization are met. This could be essential where animal handlers or members of the public assist with veterinary examinations or care for an animal that has been injected with radioisotopes.

In the case of incidents or near incidents or in the case of abnormal events, such as the loss of a source or the exceeding of a dose limit, it is advisable that the regulatory body be informed. The need for notification of such incidents or near incidents, and the practical requirements for such a notification, can be established by the regulatory body. The regulatory body may then communicate these to veterinary facilities in the form of the provision of expertise in order to avoid any other incidents or near incidents.

2.4.3. Registrants and licensees

In veterinary uses of ionizing radiation, the primary responsibility for radiation protection and safety rests with the person or organization responsible for the veterinary radiation facility — usually the registrant or licensee. Relevant requirements for ensuring radiation protection and safety in a veterinary radiation facility are established in GSR Part 3 [2]. Almost all the requirements, in particular the requirements for occupational radiation protection that apply in
veterinary uses of ionizing radiation, place responsibilities on the registrant or licensee as well as on the employer.

However, veterinary use of ionizing radiation usually involves a multidisciplinary team led by a veterinarian who is often not the registrant or licensee of the authorized veterinary radiation facility. The responsibility for radiation protection for workers and for members of the public then lies with the veterinarian responsible for the particular radiological procedure.

Registrants and licensees are responsible for ensuring that staff in the veterinary practice have adequate knowledge and competence to perform the assigned tasks.

2.4.3.1. Management system

The application of the requirements for radiation protection and safety of GSR Part 3 [2] to the use of radiation in veterinary medicine needs to fit with application of the set of requirements that ensure good veterinary practice. Management of the veterinary radiation facility needs to ensure complementarity between the requirements for radiation protection and safety and other requirements for the delivery of animal care within the veterinary facility. This complementarity is achieved through an appropriate management structure and management system.

GSR Part 3 [2] establishes a specific requirement for ensuring that protection and safety are effectively integrated into the overall management system of a given organization (GSR Part 3 [2], Requirement 5). In this Safety Report, this applies to the registrant or licensee of the veterinary facility. GSR Part 3 [2] establishes additional requirements on the protection and safety elements of the management system, for promoting a safety culture, and for taking into account human factors (GSR Part 3 [2], paras 2.47–2.52).

Further requirements for facilities and activities in general are established in GSR Part 2 [6] and recommendations are provided in Safety Guide GS-G-3.1 [7]. The development and application of the requirements for a management system is subject to the application of the requirement for a graded approach; that is, the level of elaboration of the management system needs to be appropriate for the size of the veterinary facility and the complexity of the services it provides.

The requirements for quality management will not be discussed further in this Safety Report other than to emphasize that effective management for protection and safety depends on commitment at the highest level of management in the veterinary facility, including the
provision of all the necessary resources. The following guidance is limited to those elements of the management system relating to protection and safety.

GSR Part 3 [2] establishes requirements for a protection and safety programme in general (GSR Part 3 [2], paras 2.42–2.43); for a description of the planned and systematic actions necessary to provide adequate confidence that the requirements for protection and safety are fulfilled (that is, a quality assurance programme) (GSR Part 3 [2], para. 2.48(b)); and for a radiation protection programme for occupational exposure (GSR Part 3 [2], Requirement 24). All three of these programmes are would be part of the overall management system of the veterinary facility. Detailed guidance on the radiation protection programme for occupational exposure and the quality assurance programme is given in Sections 3-5.

Application of the management system also has to ensure the promotion of safety culture, the regular assessment of safety performance and the application of lessons learned from experience. Safety culture includes individual and collective commitment to safety on the part of the leadership, the management and personnel at all levels (GSR Part 3, para 1.12).

Over the last 30 years, the concept of safety culture has been a vital element in discussions about safety in many industries. This reflects recognition that, while engineered controls to control risks are essential, it is equally important to obtain the commitment of the workforce to treat safety as a priority through a commitment by the registrant or licensee to achieve high levels of safety. There are a number of publications aimed at strengthening and measuring safety culture in facilities [8, 9, 10] and in human health care [11, 12]. There has recently been a report published on an initial study to measure safety culture in veterinary practices [13].

The management system needs to promote continuous improvement, which implies a commitment by staff to strive for continuous improvement in the veterinary uses of ionizing radiation. Feedback from operational experience and from lessons identified following accidental exposures or other incidents such as near misses needs to be applied systematically, as part of the process of continuous improvement.

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2 The veterinary facility may be a stand alone entity, or it may be part of a larger organization, such as part of a veterinary department in a university. The focus of this section on the management system is at the level of a veterinary radiation facility. However, where the veterinary radiation facility is part of a larger organization, the management system of the veterinary radiation facility will be part of the management system of the larger organization.
The management system needs to provide for record keeping and access to records. Details are provided in Sections 3–5.

2.4.3.2. The radiation protection officer

The radiation protection officer is a person technically competent in radiation protection and safety matters relevant to a specific type of practice, who is designated by the registrant or licensee or by the employer to oversee the application of relevant requirements [2].

For a veterinary radiation facility, the radiation protection officer oversees the application of requirements for radiation protection for occupational exposure and public exposure. The radiation protection officer may also provide general advice on radiation protection to the registrant or licensee.

The radiation protection officer can be, but does not have to be, a veterinarian, but could be another person who has been trained and designated by the owner of the facility. The additional education and training required for a radiation protection officer will depend on the type and complexity of the technology and on the practice of the veterinary radiation facility. In some facilities, multiple radiation protection officers may be designated.

2.4.3.3. Veterinarians

Veterinarians work independently to perform or to oversee diagnostic or therapeutic procedures in animals. In veterinary applications, such procedures are performed only by a veterinarian properly trained and registered, accredited or certified for such work [14]. It is advisable that veterinarians be formally recognized by the regulatory body as qualified for the use of ionizing radiation before performing such procedures.

It is also advisable that veterinarians be informed and trained about technological advances in relation to such procedures and about the implications of such advances for measures for radiation protection.

For veterinary radiological procedures, the referring veterinarian is usually responsible for the veterinary examination that determines the procedures to be performed. It is advisable that the veterinarian who carries out the radiological procedure collaborates with the referring veterinarian for planning the exposure for the animal.
The operator\(^3\) then performs the procedure and informs others of the possible risks or of any assistance needed during the procedure. Usually, a veterinarian is the operator, and has the responsibility for informing the animal owner and all staff and animal handlers involved in the procedure of the possible risks associated with the exposure. Photographs of an operator during veterinary radiological procedures are presented in Figs 1 and 2.

![Operator with horse](image)

**Fig. 1.** The setup for taking a radiograph of the leg of a horse with one person (the operator) in the stable. In this case the horse is tied up to a wall, and the operator holds the plate and presses the exposure button of the X ray machine. Depending on the temperament of the horse, it may be advisable to have a person holding the horse rather than tying it up to a wall. Note that a warning sign is used to mark the temporary controlled area. (Courtesy: ??)

\(^3\) ‘Operating personnel’ (or operators) is defined in the IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection: 2016 Revision (http://www-ns.iaea.org/downloads/standards/glossary/iaea-safety-glossary-rev2016.pdf) as “Individual workers engaged in the operation of an authorized facility or the conduct of an authorized activity”. In the context of this Safety Report, veterinarians will usually be operators in this sense. In some countries, veterinary technologists are allowed to be operators to perform some procedures.
Fig. 2. The setup for a radiotherapy procedure for a dog under general anaesthesia. The operator is responsible for the positioning of the dog in the beam and for the radiation exposure of the dog. The anaesthetist is responsible for the care of the dog under anaesthesia during the radiotherapy procedure. (Courtesy: ??)

2.4.3.4. Veterinary technologists and/or nurses

Veterinary technologists and nurses can participate in procedures using ionizing radiation. They need to have appropriate education, training and qualification so that they understand their responsibilities and can perform their duties competently, with appropriate judgement and in accordance with procedures [2]. Responsibility for the individual examination is usually assigned to the veterinarian. In some countries veterinary technologists are allowed to perform some radiological procedures; that is, they may be operators for some procedures. In this case, it may be advisable to require specific additional education and training, on the basis of the level of responsibility assumed.

2.4.3.5. Qualified expert in radiation protection

A qualified expert in radiation protection has the knowledge, training and experience necessary to give advice in relation to radiation protection to ensure the protection of individuals. The qualified expert’s qualifications and expertise in this respect is required to be formally recognized by the regulatory body or other relevant authority (Ref. [2], para. 2.21(b)).
2.4.3.6. Other individuals assisting with veterinary radiological procedures

The veterinary use of ionizing radiation may take place in a dedicated room in a veterinary facility (whereby the owner takes the animal to the veterinary facility). It may also take place outside the veterinary facility, such as in stables on a farm (whereby the veterinarian takes the radiological equipment to the animal).

In many situations, the need for animal handling necessitates the presence of additional individuals in the room, or in the stables or on a farm, during radiological procedures. This may necessitate additional protective measures (see Fig. 3).

Such additional individuals may include:

(a) Animal handlers, who may be members of staff of the veterinary facility or other workers (e.g. farm hands, yard staff);

(b) Animal owners and other members of the public, who may assist with calming the animal during the procedure and care for the animal upon discharge.
Fig. 3. For some X-ray imaging procedures, several individuals need to be in the room or in the stables during the procedure. In this example of a horse undergoing an X-ray of the lower leg, the operator (the veterinarian) is operating a portable X-ray unit; an animal handler is holding the leg of the horse in position; an assistant is positioning the long handled plate holder; and another animal handler is holding the horse. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent, Belgium.)

2.4.4. Referring veterinarians

A referring veterinarian is the veterinarian who initiates the request for a radiological procedure. A referral can be considered a ‘request for a professional consultation or opinion’ rather than an ‘instruction or order to perform’. For this reason, it is advisable that the referring veterinarian indicates on the request any applicable information on the veterinary context and on the history of the animal that informed the decision making process.

2.4.5. Suppliers and manufacturers

Suppliers and manufacturers of radiological equipment and software influence the delivery of radiation and have responsibilities with regard to the design and performance of the radiological equipment and software. Relevant requirements are established in GSR Part 3 (Ref. [2], para. 3.49). Registrants and licensees who are manufacturers or other suppliers of
radiation generators and radioactive sources are required to ensure that the following responsibilities are discharged, as applicable:

(a) “Supplying a well designed, well manufactured and well constructed radiation generator, which necessitates that it:

(i) Provides for protection and safety in accordance with the requirements of the IAEA safety standards;

(ii) Meets engineering, performance and functional specifications;

(iii) Meets quality standards commensurate with the significance for protection and safety of systems and components, including software;

(iv) Provides clear displays, gauges and instructions on operating consoles in appropriate language understandable to users.

(b) Ensuring that radiation generators and radioactive sources are tested to demonstrate compliance with the relevant specifications.

(c) Making information available, in the appropriate user language understandable to users, on the proper installation and use of the radiation generator or radioactive source and on its associated radiation risks, including performance specifications, instructions for operating and maintenance, and instructions for protection and safety.

(d) Ensuring that the protection provided by means of shielding and protective devices.”

Suppliers or manufacturers of radiation generators and radioactive sources, both sealed sources and unsealed sources, can influence the delivery of radiation, and therefore they have responsibilities with regard to their design and manufacture and their performance (Ref. [2], para. 1.8).

Suppliers and manufacturers of radiation generators and radioactive materials are required to be authorized. The veterinary facility that purchases radiation generators and radioactive material are also required to be authorized (usually by means of a licence) for the intended use (Ref. [2], Requirement 7, paras 3.5, 3.8, 3.9, 3.55(c)). Appropriate measures are required to be taken for the transport of radioactive material, including equipment containing radioactive material [15] and for security (Ref. [2], para. 3.53; [16]).

Suppliers and manufacturers need to provide specific training and to advise users on the correct operation of their equipment and materials if so requested by the registrants or licensees (Ref. [2], paras 2.44, 3.76(b)).
2.4.6. Maintenance and/or service engineers

Maintenance and servicing of radiological equipment is usually performed by an engineer or technician employed either by a company offering such services (which may also be the manufacturer and/or the vendor) or by the veterinary facility itself (for example, as part of an engineering and/or a veterinary engineering or service department).

When radiological equipment is being serviced, the equipment is not to be used for veterinary imaging until the service has been completed. The engineer or technician follows radiation protection rules, general health and safety rules, and procedures established by the employer, as well as the relevant rules and procedures of the veterinary radiation facility. Maintenance or service engineers need to provide records of tasks performed, as requested by registrants or licensees.

2.5. EDUCATION, TRAINING, QUALIFICATION AND COMPETENCE

Veterinary uses of ionizing radiation involve professional staff performing radiological procedures: diagnostic examinations, interventional procedures or treatment. In each case, radiation protection and safety for occupational exposure and public exposure associated with the radiological procedure depends strongly on the skills and expertise of the veterinarians involved.

The education, training, qualification and competence of the relevant professional staff therefore underpin radiation safety in veterinary uses of ionizing radiation. GSR Part 3 [2] establishes requirements for education and training for all persons engaged in activities relevant to radiation protection and safety. GSR Part 3 requires that the government be responsible for ensuring that requirements for education, training, qualification and competence are established and that arrangements are in place for the provision of the necessary education and training.

The development and adoption of a national strategy for education and training on the basis of a national assessment of needs can be useful in this context. Further, the regulatory body will need to verify the application of the requirements for education, training, qualification and competence in radiation protection, in its assessment of an application for authorization and in its periodic regulatory inspections of the veterinary facility.
Finally, the registrant or licensee of the veterinary facility has the responsibility to ensure that all the veterinarians in that facility with responsibilities for protection and safety have appropriate education, training, qualification and competence.

In the veterinary profession, the level of qualified training in radiation protection may vary between regions. There is a major part to be played for veterinary schools, continuous professional development companies and national veterinary boards, as well as international specialty colleges in radiology and radiotherapy, for promoting training and certification in radiation protection for veterinarians and veterinary technologists. Veterinary qualified experts in radiology and radiotherapy and veterinary radiation protection officers may also be directly involved in training other individuals in the profession.

GSR Part 3 [2], in para. 3.110, requires employers, in cooperation with registrants and licensees, to provide, among other things, specific instruction and training for protection and safety as it pertains to their veterinary facilities. This applies not only for new staff but also for all staff as part of their continuing professional development. Specific instruction and training are to be provided when new veterinary radiological procedures, equipment, software and technologies are introduced.

The objectives of the training include imparting knowledge of health risks associated with their occupational exposure and mechanisms of risk reduction, as well as training for operating specific equipment and for performing specific procedures.

Equipment specific training is usually provided externally by the applications specialist of the manufacturer, or in-house by a suitably qualified trainer, and augmented by use of the equipment manual. Descriptions of best practice procedures can also be found in the scientific literature.

In addition to knowledge, skills and competences relating to radiation, individuals involved in veterinary imaging procedures also have to be competent in handling the animals. They need to be aware that animals in pain and/or in unfamiliar surroundings and sedated animals may behave differently than they do in normal circumstances. They need to understand the risks involved in working with animals and to be confident that they can perform their allocated duties.

An example of the necessary knowledge, competences and skills for veterinarians and veterinary assistants are those developed by the Heads of European Radiological Protection Competent Authorities (HERCA) and described in detail in the Guidelines on Radiation
Protection, Education and Training of Veterinary Professionals [17]. The HERCA Guidelines are included as an Annex.

Further guidance on education and training is provided in sections 3.3.5, 4.3.5 and 5.3.6.

3. RADIATION PROTECTION AND SAFETY IN VETERINARY DIAGNOSTIC RADIOLOGY USING X RAYS

3.1. GENERAL

Veterinary diagnostic radiology using X rays includes the use of radiography (both diagnostic radiography and interventional radiography) and computed tomography.

Diagnostic radiography in veterinary medicine includes the use of stationary, mobile and portable equipment in veterinary facilities and the use of portable equipment (and, rarely, mobile equipment) in ambulatory practice. Ambulatory radiography necessitates the use of temporary controlled areas in field, stables or barns, and the procedure is often performed with the help of members of the public. All these situations necessitate special considerations for purposes of radiation protection.

Interventional radiography and computed tomography are performed in veterinary facilities and are performed by workers who are subject to occupational exposure.

Section 3 provides general advice applicable to all the foregoing and discusses specific needs where applicable.

Individuals involved in veterinary diagnostic radiology include workers and members of the public. The operator is a suitably trained worker. Assistants (e.g. the person who holds the plate in place for radiography of horses) may be workers (e.g. animal handlers employed by the veterinary facility or employed by the owner of the animal) or members of the public (e.g. animal owners).

3.2. SAFETY OF VETERINARY RADIATION FACILITIES AND RADIOLOGICAL EQUIPMENT

3.2.1. Veterinary radiation facilities

In small animal practice and in referral equine practice, fixed facilities are usually available. In ambulatory practice, which is primarily equine, but also farm work and work with zoo animals, suitable temporary areas for radiography have to be identified for imaging purposes. Within a veterinary facility it may also be necessary to set up a temporary controlled
area where mobile equipment or portable equipment is to be used in rooms, in stables or in operating theatres.

3.2.1.1. Fixed facilities: design of X ray rooms

The ‘as low as reasonably achievable’ principles of time, distance and shielding need to be considered when designing a room or converting an existing room for the use of X rays. Fixed facilities are rooms dedicated to the acquisition of radiographs. The controlled area is usually defined as the entire room.

In many veterinary practices, imaging rooms may be multi-purpose and may be used for imaging with X rays as well as for non-radiological purposes. It is desirable, but not essential, that the room is dedicated to radiography. However, when radiography is in process, the room may only be used for any other purpose simultaneously if adequate radiation protection is provided.

Computed tomography scanners and interventional radiography equipment need to be installed in dedicated rooms.

Radiation safety is integral to the design plans for new facilities or remodelled facilities. The necessary arrangements are carried out in consultation with radiation protection officers and qualified experts in radiation protection.

The layout of the entire clinic needs to be considered. Account needs to be taken of both safety aspects and practical considerations. The practical considerations include space for X ray generators, storage of imaging plates, and proper storage of lead aprons and ancillary equipment used for the positioning and restraining of animals.

The arrangements for power supply need to be discussed with the equipment providers and/or manufacturers, and backup power systems may need to be installed.

Considerations for the final installation of imaging equipment in fixed facilities need to include provisions to prevent the direct incidence of the X ray beam on any doors. In the case of computed tomography, the isodose curve of the specific scanner that is to be installed has to be taken into account in the layout of the room.

In general, larger rooms are preferable to allow for adequate distance and additional shielding. In equine practice, larger rooms provide additional space to move out of the way if a less cooperative animal is being imaged. Larger rooms also permit the use of mechanical restraints for the horse, such as stocks, that increase general safety.
The design of a fixed facility includes consideration of an air conditioning system sufficient to maintain the temperature in examination rooms as well as in areas with computer equipment and imaging detectors. The temperature needs to be maintained within the range specified by the manufacturers of the equipment. It also needs to be consistent with any requirements for the control of temperature and humidity for human occupancy for purposes of health and safety.

3.2.1.2. Shielding

Shielding includes structural and ancillary protective barriers which are best considered at the design stage and which need to be consistent with the intended future use of the room. Specifications for shielding, including shielding calculations, need to be prepared by a qualified expert and the radiation protection officer.

In some countries, there may be a requirement for designs for shielding and reviews of plans for shielding to be submitted to the regulatory body for review and/or approval prior to any construction. The adequacy of the shielding needs to be verified, preferably during construction and certainly before the room is put into veterinary use, as well as after any structural modifications.

For radiography, all possible intended directions of the X ray beam need to be taken into consideration in the design of the room so that the X ray beam cannot be directed at any area which is not shielded and thereby lead to unintentional exposure of workers. For procedures with small animals, the X ray beam is most commonly directed vertically, whereas in practice with horses a horizontal beam is used in most applications.

Walls, floors, doors, windows and penetrations in any of these are subject to review of and requirements for shielding. A protective barrier needs to be placed at the control console to shield operators during procedures, thus reducing the need for protective clothing (see Fig. 4).
3.2.1.3. **Light levels**

The windows in the controlled area need to be fitted with blackout blinds. The light switch needs to incorporate a dimmer switch to lower the light level sufficiently for the operator to see the light field representing the outline of the X-ray beam. This enables correct positioning, reducing the need for repeat exposures, and better collimation, thereby reducing scattering of radiation.

3.2.1.4. **Warning signs**

Signs and warning lights, conspicuously positioned, need to be used at the entrances of controlled areas to prevent inadvertent entry. For controlled areas, GSR Part 3 [2] requires the use of the trefoil symbol as specified by the International Organization for Standardization [18]. The signs need to be clear and easily understandable. Illuminated signs or flashing warning lights are typically actuated outside the room when radiation is being generated inside the controlled area.

3.2.1.5. **Image reading**

The trend in veterinary medicine is towards computerized and digital radiography. Provision needs to be made to display, to store suitably and to recall imaging studies. To enable the veterinarian to interpret images, they can be displayed in rooms specially designed for
viewing purposes. Such rooms need to have suitable levels of ambient light. They also need to be equipped with ergonomic workstations designed for image processing and manipulation so that reporting can be performed accurately. The viewing monitors of the workstations need preferably to meet medical standards to ensure optimal image quality.

3.2.1.6. Ambulatory practice

In veterinary practice, many X ray procedures are performed outside veterinary settings, such as in stables, farms or zoos; but also in a veterinary facility, when using mobile units or portable units in rooms or in operating theatres. In these instances, a temporary controlled area needs to be established to which access is restricted.

Temporary controlled areas need to be demarcated visually by means of cones, tape or portable signs. The temporary controlled area follows the same considerations as the establishment of a designated X ray room: the distance and direction of the X ray beam has to be considered. Ambient light of a suitable level is necessary to allow visualization of the area of the light beam diaphragm for proper positioning and collimation.

The temporary controlled area could be the horse's stable, for example, with the beam directed towards the brick back wall, the stable alleyway blocked off and the lights turned off. If the stable is wooden, access to the other side of this wall needs to be controlled.

Alternatively, the procedure could be performed in an open area where there is enough space to avoid people unintentionally walking into the controlled area and being exposed. Lead screens behind the X ray plate can be used to minimize the risk of accidental exposure when using horizontal beams.

For any such imaging, an appropriate power supply is needed with reliable connections. The exposure button needs to be on a cable that extends more than 2 m from the axis of the primary X ray beam so that the operator can stand this far away.

3.2.2. Radiological equipment

3.2.2.1. Purchase of equipment

X ray generators and receptors need to be compatible with their intended use. For example, many of the proximal areas of the horse require high exposures and can only be performed with high output, stationary generators, often in conjunction with a power grid. Since horses are usually radiographed standing, the duration of exposures has to be kept to a minimum to avoid blurring from movement.
Procedures are necessary for the purchase, installation, acceptance, commissioning, use, maintenance and quality control of all equipment (hardware and software). The procedures need to be developed with the involvement of a qualified expert in radiation protection, together with professionals in veterinary radiology as appropriate and the radiation protection officer.

When purchasing equipment, it is advisable to check that the equipment meets the guidelines and/or certification of the International Electrotechnical Commission and the International Organization for Standardization.

The International Electrotechnical Commission has issued international technical standards applicable to medical radiological equipment. An up to date list of standards of the International Electrotechnical Commission may be found on its web site4.

The International Organization for Standardization also publishes international technical standards that may be applicable to medical radiological equipment. An up to date list of standards of the International Organization for Standardization may be found on its web site5.

Registrants and licensees are responsible for the radiation safety of the radiological equipment used. Registrants and licensees therefore need to set specifications for the purchase of new radiological equipment that include conditions to meet the relevant technical standards of the International Electrotechnical Commission and the International Organization for Standardization, and/or equivalent national standards. In some countries, veterinarians may need to consult the agency for medical devices or a similar organization that can give type approval for different makes and models of radiological equipment.

In veterinary medicine, it is common practice to use medical radiological equipment, often second hand. Second-hand equipment needs to be checked and refurbished as necessary by a reputable company to ensure that it meets the guidelines of the International Electrotechnical Commission and the International Organization for Standardization.

Instruction manuals need to be provided with the radiological equipment. The registrant or licensee needs to ensure that there will be technical personnel available who can maintain the equipment and who can train the operators in the use of the machines. Detailed recommendations and guidelines on the design features of medical radiological equipment are

4 The International Electrotechnical Commission’s web site address is http://www.iec.ch.
5 The International Organization for Standardization’s web site address is http://www.iso.org.
provided in an IAEA Safety Guide on Radiation Protection and Safety in Medical Uses of Ionizing Radiation [19].

3.2.2.2. Maintenance of equipment

GSR Part 3 [2] establishes requirements for maintenance of radiological equipment to ensure that the equipment meets the design requirements for protection and safety and to prevent accidents as far as reasonably practicable.

The registrant or licensee needs to establish the necessary arrangements for maintenance with the manufacturer’s representative when purchasing the equipment. This can be achieved by means of a maintenance contract (for preventive maintenance and corrective maintenance) with the manufacturer.

Alternatively, an appropriately trained and authorized engineer or technician employed by the veterinary practice or by a third party contractor could carry out the maintenance.

Maintenance and servicing of equipment needs to be done at the intervals recommended by the manufacturer or by the regulatory body.

Maintenance of radiological equipment includes not just the equipment and its hardware, but also software, networks, databases, viewing monitors, view boxes and other supporting systems. In addition to the X ray generating parts of the radiological equipment, ensuring the electrical safety and mechanical safety of the equipment are an important part of the maintenance programme.

The electrical safety and mechanical safety of the radiological equipment can have direct or indirect effects on radiation safety and they need to be included in the maintenance protocol. A record of completed maintenance (preventive and corrective) needs to be kept for each piece of equipment.

3.2.2.3. Film processing

For radiation facilities where film is being used as an image receptor, film processing is crucial in ensuring that the veterinary exposure delivered results in a diagnostic image. Automatic film processors need to meet appropriate standards.

If manual processing is being performed, specially designed developer tanks, fixer tanks and washing tanks need to be used, with processing times that are based on the temperature of the developer. The darkroom for processing needs to meet relevant international and/or national standards for light tightness. It also needs to be equipped with an appropriately filtered safe
light, compatible with the film being used. Detailed guidance and information on film processing can be found in Refs [20–22].

For veterinary facilities in which film is the medium from which the image is read (e.g. a printed digital image), the printing process is crucial in ensuring that the exposure results in a diagnostic image. The resolution of the printer is not to be less than the resolution of the detector, so that the image quality of the final image is not reduced or compromised.

View boxes, for viewing films, need to have sufficient uniform brightness for diagnosis, and the colour of view boxes needs to be matched through the complete set of view boxes. Masks need to be available to restrict the illuminated area of the radiograph so as to avoid dazzling. Detailed information on viewing boxes is provided in Refs [21–22].

3.2.2.4. **Protective clothing**

Each X ray generator needs to have its own set of protective clothing, including lead aprons, gloves, thyroid protectors and protective glasses, as appropriate. Protective clothing needs to be taken care of and needs to be checked periodically. Aprons need to be of the appropriate size and to fit the individual. Lead aprons are not to be folded as this can result in cracks in the lead; provision needs to be made for hanging up all aprons (see Fig. 5). Additional information on protective clothing is provided in Appendix 1.

![Fig. 5. Storage of lead aprons. (Courtesy: ??)](image)
3.2.2.5. Positioning aids

Restraints and positioning equipment can facilitate imaging procedures and reduce the need for manual restraint of animals necessitating additional persons in the imaging area. Adequate sedation of animals can minimize risks as well as radiation exposure. For appropriate choices of sedation, the depth and duration of sedation necessary need to be considered.

Sandbags, foam pads and ropes can help in positioning small animals when sedation or general anaesthesia is not needed or is contra-indicated (see Fig. 6). Blocks can be used to raise the animal to allow the beam to be centred on the area of interest (see Fig. 7).

Fig. 6. Positioning equipment to hold a dog in position during an X ray procedure. Note that the beam has been collimated to the area of interest for the X ray. (Courtesy: ??)
The setup for lateromedial foot radiography of a horse. The front legs of the horse are positioned on blocks to allow the X-ray beam to be centred on the foot. The plate is positioned using a long handled holder. (Courtesy: ??)

Stocks are used for large animals in some facilities. Stocks provide a degree of mechanical constraint; however, they hinder access to some anatomical areas, especially the extremities. A head stand, where the sedated horse can rest its muzzle, helps to minimize movement and helps to reduce the need for repeat radiographs (see Figs 8 and 9).

Positioning blocks are commonly used to standardize radiographic projections of the horse’s foot and may be used as plate holders. Plate holders with long handles are used to allow the individual holding the plate to maximize his or her distance from the radiation source. For radiography of the spine and thorax, plate holder stands are advisable; these eliminate the need for a person to be holding the plate during the high exposures necessary for these areas.

The physical safety of the individuals participating in the examination needs to be taken into consideration together with radiation safety. For example, in radiographing the stifle joint (rear leg) of a sensitive horse, the use of a plate holder increases the likelihood of an adverse reaction by the horse. Holding the plate by hand in a lead glove while collimating the beam is considered the safer option (see Fig. 10).
Fig. 8. A standing horse positioned for a computed tomographic examination of the head. The head is stabilized in the computed tomography gantry with a plastic cradle commonly used for imaging of babies in hospitals. The horse has a rope halter to avoid the metal artefacts associated with the buckles on standard head collars. It also has cotton wool ear plugs to avoid its being startled by the noise of the computed tomography equipment. (Courtesy: ??)

Fig. 9. A standing horse positioned for a computed tomographic examination of the head. The horse is appropriately sedated and has a rope halter to avoid the metal artefacts associated with the buckles on standard head collars. The person handling the horse is standing to the side of the gantry where radiation levels are lower than near the side of the horse. The head is stabilized with a plastic cradle (see Fig. 8). (Courtesy: ??)
3.2.2.6. **Anti-scatter grids**

Anti-scatter grids or other means are used to limit the degrading effect of scattered radiation on radiological images. All means of control of scattered radiation (i.e. anti-scatter grids, air gaps or moving slits) increase the exposure of the animal for the same film density. Devices for scatter control are to be used only when necessary.

3.3. **OCCUPATIONAL RADIATION PROTECTION IN VETERINARY DIAGNOSTIC RADIOLOGY USING X RAYS**

3.3.1. **General**

In veterinary diagnostic radiology, occupationally exposed workers are usually the veterinarians and those veterinary technologists who are permitted under national regulations to perform radiography.

Workers who are exposed to radiation from sources within a practice that are not required by or directly related to their work are required to be afforded the same level of protection against such exposure as members of the public (GSR Part 3 [2], para. 3.78).

Such workers include other veterinary professionals such as nurses, support staff such as animal handlers who may need to assist with the animals during a radiological procedure, and workers such as administrative personnel and service support personnel.
It is required therefore that the dose to other veterinary professionals such as nurses and support staff such as animal handlers be kept below the dose limit for members of the public. To ensure this, such staff would need to assist with the animals during radiological procedures only if the owner of the animal is unable to assist.

GSR Part 3 establishes a hierarchy of preventive measures for the protection of workers to keep occupational exposure as low as possible. The highest level of protection is shielding (whereby structural shielding is preferred over ancillary shielding), followed by administrative controls and, as a last level, personal protective equipment.

Additionally, there are local rules and procedures in place in any radiology facility, which include measures to minimize occupational exposure during both normal work and unusual events. They also include measures for the wearing, handling and storage of personal dosimeters, specifying investigation levels and ensuring follow-up actions. For the practical arrangements, it is advisable to consult radiation protection experts, such as a qualified expert in radiation protection and a radiation protection officer.

Practical measures are used to optimize radiation protection by meeting the requirements for keeping exposures as low as reasonably achievable. These practical measures include:

- Designing radiation facilities and equipment for best practice in procedures, especially procedures in the use of ancillary devices;
- Correctly selecting imaging procedures on the basis of sound veterinary practice;
- Performing the imaging procedure so as to keep exposures as low as reasonably achievable. There may be considerable hazards arising from the animal itself, especially in equine practice, and in certain circumstances radiation protection may potentially be compromised.

3.3.2. Arrangements under the radiation protection programme

3.3.2.1. Classification of areas

Various areas and rooms in a radiology facility need to be classified as controlled areas or supervised areas, in line with requirements established in GSR Part 3 (Ref. [2], paras 3.88–3.92). All other rooms and areas that are not so designated are considered to be in the public domain. Levels of radiation in these areas is required to be low enough to ensure compliance with the dose limits for public exposure.
The following paragraphs give general guidance; it would be expected that final decisions by the licensee for a given veterinary radiation facility would be based on the expert advice of the radiation protection officer or of a qualified expert in radiation protection.

3.3.2.2. Local rules and procedures

Development of protocols for best practices is advisable, together with periodic review in collaboration with staff. This needs to include written standard operating procedures for each procedure. It is advisable to keep these standard operating procedures on display and readily available to all concerned, and it is advisable to provide training to all operators.

The purpose of standard operating procedures is to ensure protection and safety, and to meet the requirements for keeping exposures as low as reasonably achievable, with account also taken of any hazards that may arise from the animal itself.

A study [23] on occupational health hazards in veterinary medicine found that all veterinarians who had in the previous five years reported a dose greater than the dose limit for occupational exposure of 20 mSv had manually restrained animals in radiography as part of their job. Furthermore, 39% of the veterinarians who manually restrained animals during radiography reported accidental exposure to X rays. These findings emphasize the importance of written standard operating procedures and of training for all operators who carry out X ray procedures in veterinary medicine.

The following guidance will help to minimize radiation exposure of the operator and exposure of animal handlers who assist with the animal during the X ray procedure:

Sound veterinary practice will determine the correct choice of options for imaging modality and procedure. All veterinary indications warranting imaging procedures need to be carefully considered before deciding for radiation exposure in radiography. Selection of the imaging procedure is ideally based on scientific evidence; however, in veterinary practice, other factors such as financial constraints and the availability of the options for imaging modality will affect decisions.

Although the scientific evidence underlying veterinary diagnostic imaging has increased tremendously, information is still lacking in some areas. In these cases, sound veterinary reasoning and expert advice will guide the choice of imaging procedure.

On the basis of keeping exposures ‘as low as reasonably achievable’, it is necessary to review options for non-radiation-related imaging modalities if the veterinary benefit is
expected to be the same. Evidence based medicine, including the correct application of imaging procedures, necessitates having current knowledge and veterinary reasoning skills: it is the veterinarian’s responsibility to pursue continuing professional development.

Where possible, the animal can be adequately restrained by means of sedation or general anaesthesia and/or mechanical restraints to minimize the exposure of workers and of the animal itself.

In some situations, it is not possible to restrain the animal by means of sedation or general anaesthesia and/or mechanical restraints, and animal handlers have to hold the animal during the procedure. The safety of workers at risk of injury by an animal in such cases also needs to be taken into consideration.

It is necessary to minimize the number of people involved in imaging procedures. The operator needs to be trained to ensure that procedures are carried out safely. Nonetheless, it is often necessary to have people participating in the room to restrain the animal and to position or to hold the imaging plate. While it is advisable to perform radiography with trained staff only, in ambulatory veterinary practice, members of the public (often the animal owner) may be involved in imaging procedures (see Fig. 3). The operator needs to collimate the beam to the area of interest for diagnosis on the animal to ensure that the hands or other parts of the body of the animal handler are not in the beam (see Figs 11 and 12). An unnecessarily large beam area will also increase the amount of scatter radiation from the animal. The operator therefore also needs to inform the animal handler on where to stand to minimize exposure to scattered radiation.

The animal handlers involved need to be informed about the radiation risks associated with the procedure and they need to give informed consent to participation. To minimize the hazards associated with the animal itself and the need for repeat exposures, animal handlers who participate in procedures need to be competent.
Fig. 11. An example of how not to carry out an X ray procedure. The operator has not collimated the X ray beam down to the area of interest, and the hands of the animal handler have been exposed to the direct X ray beam. (Courtesy: ??)

Fig. 12. A second example of how not to carry out an X ray procedure. The operator has not collimated the X ray beam down to the area of interest, and the hands of the animal handler have been exposed to the direct X ray beam. (Courtesy: ??)

The need for repeat exposures can also be kept to a minimum by having adequately trained staff to perform the procedures. Exposure charts (standard operating procedures) will assist with imaging techniques, to reduce the need for repeat exposures. When students or
apprentices are in the process of learning how to perform a procedure, studies need to be done under the supervision of adequately trained staff. With advances in digital radiography systems, exposure values are lower than with previous systems. A record of the exposure values, the number of exposures, area, date and identification of the animal can be kept either digitally or on paper. Movement of the animal needs to be kept to a minimum by using adequate animal restraints.

Quality assessment needs to be performed by an appropriately trained person who is able to differentiate between images of diagnostic quality and images not of diagnostic quality, bearing in mind that diagnostic quality does not mean textbook quality.

Suggested guidelines for carrying out X ray imaging procedures are presented in Table 2.

| Guideline                                                                                                                                 |
|---|---|
| 1. | Individuals involved in the procedure are to be as far away as possible from the primary beam and from the animal being exposed, to minimize their exposure to scattered radiation; no body part of the individual is to be in the primary beam. |
| 2. | Plate holders on extensions and/or with handles are to be used, allowing the individual holding the plate to be positioned away from the beam. |
| 3. | Individuals within controlled areas are to wear protective clothing, including lead aprons, thyroid shields, lead gloves and lead glasses, as applicable. |
| 4. | Portable and/or mobile X ray devices are to be mounted on a stand and not hand held. Exceptions will depend on applicable local regulations. |
| 5. | Where possible, mobile shields are to be used; however, the benefits of mobile shields need to be considered in conjunction with the associated hazards in having a shield positioned close to the animal being imaged (owing to the possible reaction of the animal). |
| 6. | The X ray beam is to be directed away from people and doors. |
| 7. | Verbal warnings are to be given of an imminent exposure to alert others. |
| 8. | Workers subject to exposure need to wear personal dosimeters. Members of the public such as animal owners who hold an animal or who assist during exposures usually do not need to wear personal dosimeters. |
| 9. | Members of the public who are pregnant are not to hold animals or to assist during procedures. |
| 10. | All support personnel and members of the public are to be made aware of the radiation exposure and associated hazards before assisting with procedures. |

Equipment (hardware and software) needs to be operated or used in a manner that ensures satisfactory performance at all times with respect to both the imaging tasks and radiation safety.
The manufacturer’s operating manual is an important resource, but supplementary procedures need to be developed specifically for the use of imaging in the facility.

Staff working in imaging need to understand the documented standard operating procedures and the operation of the equipment with which they are working, including its safety features. Additional training needs to be provided when new radiological equipment is installed in the facility.

3.3.2.3. Monitoring of the workplace

Monitoring of the workplace for radiation levels is necessary to ensure that proper measures for radiation protection are in place. Workplace monitoring includes measurements made in the working environment and interpretation of the results. Workplace monitoring serves several purposes, including routine monitoring; special monitoring for specific occasions, activities or tasks; and confirmatory monitoring to check assumptions made about exposure conditions.

Workplace monitoring can be used to verify the doses of personnel whose work involves occupational exposure at predictable low levels of radiation. It is used in particular for staff members who are not individually monitored. General recommendations and guidance on workplace monitoring are given in Ref. [24].

Workplace monitoring needs to be performed and documented as part of the veterinary facility’s radiation protection programme [2]. Monitoring involves measurement, and also interpretation of the results, assessment, investigation and reporting. This can lead to corrective measures being recommended, if necessary. The radiology facility’s radiation protection officer or qualified expert provides specific advice on the workplace monitoring programme, including in any investigations that arise if investigation levels have been exceeded [2].

The survey meters or portable instruments used for radiation monitoring need to be calibrated and maintained appropriately for use. The frequency of calibration and the frequency of testing are based on practices recommended by the manufacturer and regulatory bodies.

3.3.3. Assessment of occupational exposure

GSR Part 3 requires individual monitoring to be conducted for any worker who usually works in a controlled area or in areas known to involve radiation exposure; and for any worker who occasionally works in a controlled area and is likely to receive significant occupational
exposure (see GSR Part 3 [2], paras 3.99–3.102). The dose limits of GSR Part 3 [2] for occupational exposure and for public exposure are presented in Table 1.

3.3.3.1. Individual monitoring

Individual monitoring provides information about radiation exposures of workers for a record of work practices and to meet a regulatory requirement. The operator and any other staff who are identified in the safety assessment as workers subject to occupational exposure need to be individually monitored as appropriate. In particular, staff who are close to an animal during exposure need to be monitored.

In image guided interventional procedures and computed tomography, only staff members may assist with procedures. This includes the operator, other workers in imaging, and members of the surgical, nursing and anaesthesia teams.

Individual external exposures are assessed using individual monitoring devices. These include thermoluminescent dosimeters, optically stimulated luminescence dosimeters, radiophotoluminescence dosimeters, film badges and electronic dosimeters.

Real time or active monitoring devices, such as electronic dosimeters, need to be calibrated and traceable to a standards dosimetry laboratory [2, 24]. Passive detection dosimetry necessitates processing by a qualified dosimetry service and receipt of dose reports for review. Some regulatory bodies may specify a performance criterion for timely reporting.

Personal dosimeters are assigned to individuals for use during procedures in a particular facility. Personal dosimeters are not to be shared with other staff and are not to be worn in other facilities. For example, if an employee is issued with a dosimeter at a particular veterinary facility, it is to be worn at that veterinary facility only and not at any other veterinary facilities where he or she may also work.

Employees need to be advised to share dosimetry records with all their employers in order to ensure that their occupational dose limit is not exceeded. Results of personal dosimetry can then be interpreted for the employee working in a particular veterinary facility. This will allow for review of the effectiveness of the optimization of protection for that individual in that veterinary facility.

Personal dosimeters are worn for specific monitoring periods that are specified by regulatory bodies in most countries. Shorter monitoring periods, such as monthly monitoring, are often used for individuals working with procedures that yield higher occupational
exposures. Longer monitoring periods, such as periods of three months, are advised for individuals with lower exposures.

When not in use, individual dosimeters need to be kept in a dedicated place. They need to be protected from damage and from irradiation. If an individual loses his or her dosimeter, the individual needs to inform the radiation protection officer, who needs to perform a dose assessment, record this evaluation of the dose and add it to the individual’s dose record.

Where there is a national dose registry, information of the dose estimate need to be provided in a timely manner. The most reliable method for estimating an individual’s dose is to use his or her recent dose history. In those cases where the individual performs non-routine types of work, it may be better to use as the basis for the dose estimate the doses of co-workers having similar exposure conditions.

3.3.3.2. Investigation levels for workers

Investigation levels are different from dose limits and dose constraints. Investigation levels are used to provide a warning of the need to review procedures and performance, to investigate what is not working as expected and to take timely corrective action. Investigations and corrective actions need to be carried out when the dose received by a worker exceeds an investigation level.

The following are examples of investigation levels for workers in veterinary radiation facilities: monthly doses that are greater than 0.5 mSv for a dosimeter worn under a protective apron; doses greater than 2 mSv in a month [25] from an over-apron dosimeter, which may indicate that doses to the eye may be of concern; and doses greater than 15 mSv in a month for hand dosimeters or finger dosimeters [25, 26]. Abnormal conditions and/or events will also necessitate investigation.

In all cases the investigation needs to be carried out for the optimization of protection and safety for occupational exposure. Investigation levels are also to be set for workplace monitoring, with account taken of exposure scenarios and the predetermined values adopted for investigation levels for workers. Recommendations and guidance on investigation levels are provided in Ref. [24].

An investigation needs to be initiated as soon as possible following the exceeding of an investigation level or abnormal conditions and/or an event (Ref. [2], paras 1.31, 3.45–3.48, 3.94). A written report needs to be prepared concerning the cause, determination or verification of the dose received by workers, any corrective actions taken, and instructions or
recommendations to avoid recurrence. Such reports are to be reviewed by the licensee. In some cases, the regulatory body may also need to be informed.

3.3.3.3. Records of occupational exposure

Records of occupational exposure for each worker are required to be maintained during and after the worker’s working life, at least until the former worker attains or would have attained the age of 75 years, and for not less than 30 years after cessation of the work in which the worker was subject to occupational exposure (Ref. [2], para. 3.104).

As well as for demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary facility for additional purposes. These include assessing the effectiveness of the optimization of protection and safety at the facility and evaluating trends in exposure.

National or local regulatory bodies might specify additional requirements for records of occupational exposure and for access to the information contained in the records. Employers are required to provide workers with access to records of their own occupational exposure (GSR Part 3 [2], para. 3.106 (a)). Further general recommendations and guidance on records of occupational exposure are provided in Ref. [24].

3.3.3.4. Workers’ health surveillance

The primary purpose of workers’ health surveillance is as medical supervision intended to ensure the initial and continuing fitness of workers for their intended tasks. Relevant requirements are established in GSR Part 3 [2], paras 3.108 and 3.109.

No specific workers’ health surveillance relating to radiation exposure is necessary for staff involved in veterinary diagnostic radiology or image guided interventional procedures. One possible exception is an initial eye assessment and periodic eye assessments for visual acuity and contrast resolution for personnel performing significant numbers of image guided interventional procedures.

Special investigations involving biological dosimetry and further extended diagnoses and medical treatment would be necessary only if workers are exposed at doses much higher than the dose limits (e.g. doses of a few hundred millisieverts or higher) [24].

Under normal working conditions, the doses incurred due to occupational exposure in veterinary diagnostic radiology and image guided interventional procedures are low. No specific radiation related examinations are necessary for persons who are occupationally
exposed to ionizing radiation, as there are no diagnostic tests that yield information relevant for exposure under normal working conditions.

It is therefore rare for considerations of occupational exposure arising from the working environment of a veterinary radiology facility to influence significantly decisions about the fitness of workers to undertake work with radiation, or to influence the general conditions of service [24].

Counselling needs to be made available to workers who have had exposures in excess of dose limits, or who may have been exposed in excess of dose limits, and information, advice and, if indicated, counselling is to be made available to workers who are concerned about their radiation exposure. In diagnostic radiology and in image guided procedures, workers who are concerned about their radiation exposure may include female workers who are pregnant or who may be pregnant. Counselling is to be given by appropriately experienced and qualified practitioners. Further guidance is given in Ref. [24].

3.3.4. Conditions of service and special arrangements

As required in GSR Part 3 [2], para. 3.111, special compensatory arrangements, or preferential consideration with respect to salary, special insurance coverage, working hours, length of vacation, additional holidays or retirement benefits, are neither to be granted nor to be used as substitutes for measures for protection and safety, in accordance with the requirements of GSR Part 3.

3.3.4.1. Female workers who are pregnant

It cannot in GSR Part 3 [2] be made a requirement on a female worker to notify an employer of a suspected pregnancy or of breast-feeding. However, it is necessary to ensure that female workers understand the importance of making such notifications so that their working conditions may be modified accordingly (Ref. [2], para. 3.113).

GSR Part 3 [2] establishes requirements for employers, in cooperation with registrants and licensees, to provide female workers who are liable to enter controlled areas or supervised areas or who may undertake emergency duties with appropriate information in this regard (GSR Part 3 [2], para. 3.113(b)).

The employer of a female worker, who has been notified by the female worker of her suspected pregnancy or that she is breast-feeding, is required to adapt her working conditions in respect of occupational exposure to ensure that the embryo or fetus or the breastfed infant is
afforded the same broad level of protection as is required for members of the public (GSR Part 3 [2], para. 3.114).

The limitation of the dose to the embryo or fetus does not mean that a female worker who is pregnant is required to avoid work with radiation. The employer is, though, required to carefully review the working conditions with regard to exposure and potential exposure for female workers who have notified their employer of their suspected pregnancy.

A possible adaptation is the reassignment of a female worker who is pregnant to a location that may have a lower ambient dose equivalent; for example, from interventional radiology to radiography or to computed tomography. Such reassignments need to be accompanied by adequate training.

When the public dose limit of 1 mSv is applied for the embryo or fetus, the reading of a dosimeter may overestimate the dose to the embryo or fetus by a factor of 10. The dose to the fetus may be monitored by using an additional dosimeter appropriately positioned [24]. Information, advice and, if indicated, counselling for female workers who are pregnant needs to be made available.

3.3.4.2. Persons under 18 years of age

In many States there is the possibility of students of age 16 years or more, but under the age of 18 years, who are undertaking studies and training to become a veterinary technologist may be subject to exposure. GSR Part 3 [2], para. 3.116, establishes requirements on access to controlled areas for persons under the age of 18 years, and the dose limits for such persons are more restrictive; see Table 1.

3.3.5. Education, information, instruction and training

General guidance regarding education and training of veterinary professionals is presented in Section 2.5. The following guidance is additional guidance that is applicable to veterinary professionals working in diagnostic radiology and interventional radiology.

The objectives of the training include imparting knowledge of risks associated with radiation and mechanisms of risk reduction as well as training for operating specific equipment used for diagnostic imaging and interventional radiology in the veterinary facility, and for performing specific procedures. Equipment specific training is usually provided by the applications specialist of the manufacturer, externally or in-house by a suitably qualified trainer and augmented by use of the equipment manual. Descriptions of best practice procedures can also be found in the scientific literature.
An example of the education and training in radiation protection for veterinary professionals are those developed by the Heads of European Radiological Protection Competent Authorities (HERCA) [17]. The HERCA guidelines are included as an Annex. The HERCA guidelines include Table A-1 Core Learning Outcomes in Radiation Protection for Veterinary Doctors and Table A-4 Additional Learning Outcomes for Veterinary Doctors working in the Field of Interventional Radiology that contain the knowledge, skills and competencies for veterinary practitioners.

The HERCA guidelines also include Table A-5 Core Learning Outcomes in Radiation Protection for Veterinary Radiographers and Veterinary Assistants and Table A-8 Additional Learning Outcomes for Veterinary Radiographers and Veterinary Assistants working in the Field of Interventional Radiology that contain the knowledge, skills and competencies for veterinary technologists.

HERCA note that the education and training requirements need to be met before veterinary professionals before they start work with radiation. HERCA also note that veterinary radiographers and veterinary assistance do not have to meet all the requirements set out in the document, depending on the scope of practice and the degree of autonomy that they are permitted in their country.

Veterinary practitioners need to be given the responsibility to provide information, instruction and training to other staff in the veterinary facility. These staff include veterinary nurses and animal handlers who may be required to assist in the performance of radiological procedures. They also need to provide information on the risks related to the use of radiation.

Veterinary practitioners need to be given responsibility for providing appropriate information to animal owners on the procedures that are carried out on their animal, and to those animal owners that may be required to assist in the performance of the radiological procedures.

3.4. RADIATION PROTECTION OF THE PUBLIC

3.4.1. Animal owners and other visitors

Public exposure of persons in and around the radiology facility may arise from the performance of veterinary radiology. Some animal handlers and other staff employed by the veterinary facility will be required to be afforded the same level of protection against exposure as members of the public (see para. 3.3.1). Information needs to be provided to such persons on the relevant safety aspects and local rules.
Visitors to the veterinary facility will include animal owners accompanying animals to the veterinary facility. Such visitors may sit in a waiting room and may go along corridors to consulting rooms. Some animal owners may be asked to accompany their animals to the X ray room, and they may be asked to stay in the X ray room to assist with the animal during the procedure. Special consideration needs to be given to visitors to the facility who are under the age of 18 and to women who are or who may be pregnant.

All visitors, including persons delivering goods or supplies, sales personnel, accompanying persons and escorts, and owners of animals in the facility, are required to be afforded the same level of protection against exposure as members of the public.

3.4.1.1. Protection against external exposure

The primary means for protecting members of the public such as visitors against exposure is the shielding in place at the radiology facility. The shielding needs to be sufficient that any public exposure resulting from being in an immediately adjacent area that is accessible by visitors, including outdoors and rooms above and below the X ray room, would be in compliance with the dose limits for public exposure. The dose from public exposure would preferably also be less than any dose constraint that the regulatory body may have established.

For non-fixed (mobile, portable and ambulatory) radiography, establishing a temporary controlled area and conspicuously posting radiation warning signs will reduce the potential exposure of anyone in the immediate vicinity when mobile radiography is being performed. In these cases, a combination of distance, placement of mobile or portable shielding, and careful control of the direction of the X ray beam will ensure appropriate radiation protection for the public.

3.4.1.2. Control of access

Access to areas where radiation is being used needs to be controlled to ensure that doses from exposure of visitors are below the dose limits for public exposure and below any relevant dose constraints. Written rules need to be established for access to controlled areas and supervised areas by animal owners.

Access by visitors to X ray rooms and other controlled areas is restricted. Exceptionally, a visitor, for example a veterinarian from another facility, may be permitted to enter an X ray room or other controlled area, if accompanied at all times by a staff member who is familiar with the measures for protection and safety for the controlled area.
The radiology facility needs to have written procedures specifying where and when such exceptions can be made and who may accompany the visitor. Particular consideration, in all cases, is to be given to women who are or who may be pregnant, and to all persons under the age of 18 years.

Controlled areas and supervised areas are required to be clearly identified to help prevent inadvertent entry to areas where diagnostic radiological procedures or image guided interventional procedures are being performed (Ref. [2], paras 3.88, 3.89; [19]). Further control can be afforded by the use of keys or passwords to restrict access to the control panels of veterinary equipment to operators and authorized persons only.

3.4.2. Monitoring and reporting

The programme for monitoring of public exposure arising from veterinary radiological procedures needs to include dose assessment for exposures in the areas in and surrounding the X-ray rooms that are accessible to the public. Estimated doses can be derived from the shielding calculations made at the planning stage, combined with results from area monitoring in the initial operation of the facility and periodically thereafter. Records of dose assessments need to be kept for a period that meets any relevant regulatory requirements.

4. RADIATION PROTECTION AND SAFETY IN VETERINARY MEDICINE USING UNSEALED SOURCES

4.1. GENERAL

Section 4 covers veterinary medicine using unsealed sources (veterinary nuclear medicine): radioactive materials that are administered to animals for diagnosis or for treatment of disease. X-ray imaging such as computed tomography, which may be done in conjunction with a procedure in veterinary nuclear medicine, such as in hybrid imaging, is mainly covered in Section 3.

Procedures in veterinary nuclear medicine involve the administration of a radiopharmaceutical to the animal. For diagnostic procedures in veterinary nuclear medicine, trace amounts of compounds are labelled with photon emitters or positron emitters, forming a radiopharmaceutical. For photon emitters, the distribution of the radiopharmaceutical in the animal can be imaged by means of different modalities. In therapeutic veterinary nuclear medicine, radiopharmaceuticals for administration in therapeutic activities are usually labelled with alpha, beta or beta–gamma emitting radionuclides.
4.2. SAFETY OF VETERINARY RADIATION FACILITIES AND RADIOLOGICAL EQUIPMENT

4.2.1. Design of veterinary nuclear medicine facilities

Provision for the incorporation of radiation safety features is best made at the design stage for the facility. Account needs to be taken in the siting and layout of the workload and the movement of animals, both in the veterinary nuclear medicine rooms and in rooms for other veterinary medicine within a larger facility. Consideration needs to be given to providing easy routes for animals, after examination or treatment has been performed, that minimize their movement through the facility.

A typical veterinary nuclear medicine facility using unsealed sources has the following designated areas: area for storage and preparation of sources (radiopharmacy, radioisotope laboratory or ‘hot lab’); area for administration of radiopharmaceuticals; imaging (in vivo) area; sample measurement (in vitro) area; animal holding areas; and storage area for radioactive waste.

An example of the layout of a veterinary nuclear medicine facility is shown in Fig. 13. Examples of imaging rooms for imaging of dogs, cows and horses are shown in Figs 14–16. For veterinary nuclear medicine facilities where procedures with radiopharmaceuticals are performed, dedicated rooms or stables for holding the animals prior to and after undergoing such procedures need to be considered (see Figs 17 and 18).

All these areas are subject to meeting the requirements established in paras 3.89 and 3.90 of GSR Part 3 [2] (for controlled areas) as well as complying with local regulations. The requirements are for, among other things: the delineation of areas; signage; measures for protection and safety; control of access; provision of personal protective equipment; provision for individual monitoring and area monitoring; provision of equipment for monitoring for contamination; and provision of facilities for personal decontamination.

It is best practice to have separate rooms for preparation of radiopharmaceuticals, storage of radiopharmaceuticals, imaging and animal holding. This is often not possible, however, and areas for these purposes may be delineated within a single room with shielding applied appropriately.
Fig. 13. Example of a layout of a veterinary nuclear medicine facility. The rooms for animals are separated from the imaging (scanning) rooms. There is a separate room for the ‘hot lab’ and a room for storage of radioactive waste. Animals are injected in the ‘hot lab’. There is a separate room for cats undergoing radioiodine treatment for hyperthyroidism. There is another separate room for dogs undergoing radionuclide therapy, with a separate toilet for dogs. The red pipelines denote intake of fresh air; the blue pipelines represent the discharge circuit of air in all rooms for animals and in the ‘hot lab’. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent, Belgium.)

[[Figure boxes need to be edited.]]
Fig. 14. Dog under general anaesthesia for gamma camera imaging. This method allows the operator to remain at a safe distance from the animal. Increasing the distance from a radioactive source decreases the dose to the veterinarian, the helper and the anaesthetist. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

Fig. 15. Cow undergoing a bone scan for a suspected sacroiliac condition. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)
Fig. 16. Use of lead aprons is indicated to reduce the exposure of veterinarians and of helpers in performing an equine bone scintigraphy. Sedation is in most cases advisable. Note the protective shield covering the gamma camera to reduce damage to the crystal. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)
Fig. 17. Veterinary room for dogs treated with radioactive compounds, e.g. radioactive iodine for thyroid cancer. Note the washable walls and floor. The transition between walls and floor needs to be seamless for cleaning and to prevent the accumulation of contamination. When volatile radionuclides (e.g. radioiodine) are used, an appropriate ventilation system needs to be in place. A dog park is created to limit contamination of the room. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)
Fig. 18. A horse in a designated scintigraphy stable. The stable is marked with appropriate warning signs. Gloves and overshoes are provided in case someone needs to handle the horse, and a special waste bin is available for any waste to be collected and disposed of appropriately.

For security purposes, veterinary nuclear medicine facilities need to be located in areas where access by members of the public to rooms where the sources, including generators, and equipment for dispensing radiopharmaceuticals are used and stored can be restricted. Physical security and control of access with badges or key locks need to be provided.

Signs need to be conspicuous and clear and need to be placed at the entrances of controlled areas to alert members of the public to the possible presence of radioactive material. Signs are also needed to identify areas for the preparation and storage of sources and rooms where animals are undergoing procedures and are being held.

4.2.1.1. Areas where unsealed sources are handled

Dedicated work areas for manipulation of unsealed sources need to be identified, with equipment kept available in place specifically for this purpose. Adequate and appropriate
shielding needs to be provided during storage, manipulation and transport of the radiopharmaceuticals and of radioactive waste.

Materials for preventing contamination as well as for remediating contamination need to be kept available in place. Specific design and construction follow national regulations and are discussed with the local authorities. Ideally, a separate room is available for preparing the radiopharmaceuticals and for imaging. When no separate room is available, adequate shielding, measures to prevent contamination and measures for climate regulation are necessary.

Drainpipes from sinks in the radiopharmacy or in laboratories using radioactive material need to properly route or capture radioactive material. Requirements relating to the clearance of radioactive material need to be complied with. Drainpipes from such sinks have to connect only with other drains in the building that carry radioactive material.

It is advisable that the final plans for the drainage system that are supplied to maintenance personnel clearly identify the drains from radiopharmacies and from laboratories using radioactive material. Pipelines through which radioactive material flows need to be marked to ensure that any maintenance work is preceded by monitoring.

The ventilation system needs to be designed in such a way that the radiopharmacy and the laboratory using radioactive material are at negative air pressure relative to surrounding areas and are adequate for the radioisotopes used (see Figs 13 and 19). The source of air exchanged is to be from areas of low airborne contamination to areas where such contamination is likely.

Room air from a radiopharmacy or from laboratories using radioactive material needs to be vented through a filtration system or other mechanism for trapping airborne radioactive material; it is not to be recirculated either directly, in combination with incoming fresh air in a mixing system, or indirectly, as a result of proximity of the exhaust to a fresh air intake. Treatment facilities using volatile radionuclides (e.g. $^{131}$I) and facilities housing treated animals need to be appropriately equipped with a negative pressure ventilation system.
Fig. 19. Piping of the ventilation system to maintain negative pressure in order to reduce contamination and internal exposure of workers when working with aerosols or volatile radionuclides. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

Floors in areas of potential contamination need to be finished with an impermeable material that is washable and resistant to chemical change, and need to be curved up to the walls, with all joints sealed and glued to the floor (see Fig. 17). The walls need to be finished in a smooth and washable surface such as washable, non-porous paint. All surfaces where unsealed sources are used or stored, such as benches, tables, seats, doors and drawer handles, need to be smooth and non-absorbent for ease of cleaning and decontamination.

4.2.1.2. Rooms and stables

Floors and other surfaces of rooms designated for animals undergoing diagnostic procedures using radiopharmaceuticals or radiotherapy need to be covered with smooth, continuous and non-absorbent materials that can be easily cleaned and decontaminated. The
floors can then be covered with absorbent materials such as wood shavings that absorb contaminated urine.

4.2.1.3. Storage and management of radioactive waste

Most radioactive waste from veterinary nuclear medicine facilities is waste containing short lived radionuclides. It is feasible to deal with such waste as conventional (non-radioactive) waste, either immediately or after a period of time to allow for decay. A formal mechanism needs to be put in place, including rigorous control measures, to demonstrate compliance with regulatory requirements in respect of the clearance (removal from regulatory control) of waste material that is no longer considered to be radioactive waste. Recommendations and guidance are provided in Ref. [27].

A room for the interim storage of radioactive waste needs to be made available in the veterinary nuclear medicine facility (see Fig. 20). The room needs to be locked, to be properly marked and to be ventilated. Records need to be kept that identify the origin of the waste.

Management of the radioactive waste includes grouping (segregation) of the waste in accordance with the expected period of time necessary for the decay of the radionuclides (depending on the initial activity and the physical half-life) and the physical form of the waste.

Examples of different physical forms of waste include: vials that may contain residual radioactive material; biological waste, which may undergo decomposition; infectious waste requiring sterilization; broken glassware; syringes; needles which need to be collected in separate containers to prevent injuries; amounts of radionuclide generator; clothing from stables and kennels (for therapeutic applications); and liquid scintillation solutions.

Containers to allow segregation of different types of radioactive waste need to be provided in areas where radioactive waste is generated. The containers need to be suitable for their purpose (in terms of volume, shielding and leak tightness, for example).
In practice, it is mainly $^{131}\text{I}$ and radioactive waste from animal radiotherapy with radiopharmaceuticals that need special precautions. Appropriate storage and transport of waste to allow for decay will minimize any environmental impact of its subsequent release.

As a rule of thumb, ten times the physical half-life is considered an appropriate decay time for the clearance of radioactive waste as conventional waste (this gives a decay factor of over 1000). Most diagnostic studies are performed using $^{99m}\text{Tc}$, which has a physical half-life of 6 hours. Following storage for 2.5 days (60 hours), most of this waste can be dealt with as conventional waste.

Technetium generators contain $^{99}\text{Mo}$ with a half-life of 2.75 days; depending on their initial activity, the decay time at the veterinary nuclear medicine facility is 1.5–2 months. In positron emission tomography, $^{18}\text{F}$ is the most commonly used radionuclide. The short physical
half-life of 110 minutes generally allows clearance of waste as conventional waste within 24 hours.

Management of radioactive waste containing longer lived radionuclides depends on initial activity and half-life. The radiation protection officer at the veterinary nuclear medicine facility, together with the regulatory body, would give advice in these cases.

On the basis of these considerations, a summary of practical advice for specific situations in veterinary nuclear medicine can be given:

(a) *Technetium generators.* There are two options: (1) returning technetium generators to the supplier after use, ensuring compliance with the Regulations for the Safe Transport of Radioactive Material [15]; and (2) waiting for radioactive decay. After 1.5–2 months, the technetium generators can be dismantled and the elution column removed, as the material can then be dealt with as non-radioactive. The generator columns are checked for radionuclide contaminants with long half-lives before disposal and the labels are removed.

(b) *Used syringes and needles.* Used syringes and needles can be collected in a shielded container in rooms used for preparation and injection of radiopharmaceuticals. When the container is full, it is sealed and the expected date of its clearance (removal of regulatory control) is marked on it. After this time, the external dose rate can be monitored. The container can be cleared from regulatory control when the ambient dose equivalent rate is the same as the background or is in compliance with national and/or local regulations.

(c) *Vials containing residues of* $^{18}$F, $^{99m}$Tc, $^{67}$Ga, $^{131}$I and $^{89}$Sr. A similar procedure can be established for vials as for the syringes, but segregation on the basis of physical half-life is necessary.

(d) *Gloves, cover paper and plastic overshoes.* Gloves, cover paper and plastic overshoes are collected in plastic bags in rooms used for the preparation and injection of radiopharmaceuticals. When a bag is filled, it is sealed. After waiting for radioactive decay or with appropriate monitoring, the bags can be cleared from regulatory control and can be dealt with as conventional (non-radioactive) waste.

(e) *Sealed sources.* Sealed sources for calibration of activity meters, quality control of gamma cameras and counters, and anatomical marking of images are cleared from regulatory control as determined by the radiation protection officer in accordance with national regulations and the authorization by the regulatory body.

(f) *Small amounts of* $^3$H and $^{14}$C *in organic solutions.* Amounts of $^3$H and $^{14}$C to small
activities in organic solutions can usually be dealt with as conventional (non-radioactive) waste. In certain instances, because of their potential toxicity, special precautions may apply, and appropriate precautions for bio-hazards need to be taken.

(g) Animal excreta contaminated with radionuclides. For diagnostic veterinary medicine, there is no need for the collection of animal excreta such as urine and faeces contaminated with $^{131}$I because of the nature and half-life of the radionuclides. For therapeutic veterinary medicine, policies vary for different countries, but in principle they follow dilution methods or decay methods (e.g. either by collecting and storing excreta, or by designing facilities with drainpipes terminating in a delay tank). Bedding for horses is either left in place for the necessary period of time for decay (usually $^{99m}$Tc: 60 hours), or else collected and held in dedicated containers in dedicated waste storage facilities until decayed.

4.2.1.4. Considerations relating to shielding

The shielding of walls, floor and ceiling has to be designed to meet the requirements for optimization of protection and safety for workers and the public, and to ensure that the relevant doses limits are not exceeded. The classification of areas within the facility, the nature of the work done, and the radionuclides intended to be used and their maximum activity need to be taken into consideration.

It is convenient to shield sources, where possible, rather than to shield the room or the workers. Shielding (e.g. lead bricks, syringe shields, transport boxes) is also needed for the storage, manipulation and transport of radiopharmaceuticals.

In the case of hybrid imaging (positron emission tomography–computed tomography and single photon emission computed tomography–computed tomography), the estimated ‘nominal design dose’ in occupied areas is derived by the process of ‘constrained optimization’, i.e. selecting a source related dose constraint, with the condition that individual doses from all relevant sources are well below the relevant dose limits for the persons occupying the area to be shielded.

Care needs to be taken to avoid unrealistic overestimation of the amount of shielding necessary due to the multiplication of conservative assumptions. Such conservative assumptions are typically that: attenuation by the animal is usually not considered; decay of short lived radionuclides such as $^{18}$F is not considered; workload, use and occupancy factors
are overestimated; and the persons to be protected are considered to remain throughout where their exposure is highest in the adjacent room.

A balanced decision needs to be made and the accumulation of overly conservative measures that may not represent optimization is therefore to be avoided. Specification of shielding, including calculations, is to be performed by a qualified expert in radiation protection in collaboration with the radiation protection officer and in accordance with any relevant requirements of the regulatory body.

4.2.2. Radiological equipment, software and ancillary equipment

4.2.2.1. Imaging equipment

The performance of gamma cameras (planar and single photon emission computed tomography systems) and positron emission tomography scanners determine the efficacy of the diagnostic radiological procedures, and hence can influence what amount of activity of radionuclides needs to be administered to the animal.

Procedures for the purchase, installation, acceptance, commissioning, use, maintenance and quality control of all equipment (hardware and software) need to be developed with the involvement of a qualified expert in radiation protection, together with professionals in veterinary nuclear medicine as appropriate and the radiation protection officer.

The following specifications are important with regard to performance of the detector for gamma cameras: analysis of pulse height; uniformity; spatial resolution and linearity; energy resolution; sensitivity; count rate performance; and leakage from the shielding of the detector head.

Regular monitoring of these specifications is advisable. The specifications are usually checked during maintenance procedures by specialized firms or by the supplier of the camera system, but they can be checked by a qualified expert if there is one available. When radionuclides with energies higher than $^{99m}$Tc (140 keV) are used, dedicated collimators have to be in place.

Sodium iodide (NaI) crystals are hygroscopic and sensitive to temperature fluctuations, which necessitates control of the room for temperature and humidity.

The following characteristics are important for the performance of positron emission tomography cameras: spatial resolution; sensitivity; scatter fraction, count losses and random measurements; energy resolution; image quality and accuracy of attenuation, and scatter.
correction and quantitation; and resolution of coincidence timing for time of flight positron emission tomography accuracy. As with gamma cameras, these specifications have to be checked on a regular basis. Dedicated methods for acquisition, processing and analysis have to be available.

If hybrid systems, based on a combination with computed tomography, are used, it is advisable for the radiological equipment to meet relevant international standards of the International Electrotechnical Commission and of the International Organization for Standardization and/or equivalent national standards. Specifications concerning computed tomography can be found in Section 3 on radiological equipment.

4.2.2.2. Ancillary equipment

The veterinary nuclear medicine facility needs to have equipment, instruments and test objects for measurements, dosimetry and quality control. These may include liquid scintillation counters, well counters, activity meters (dose calibrators), probes, check sources, flood sources, phantoms, geometry test tools and mechanical test tools.

Where applicable, such instrumentation needs to comply with relevant standards of the International Electrotechnical Commission or equivalent national standards. Further guidance on appropriate equipment, instruments and test objects is given in Refs [28–31].

The veterinary nuclear medicine facility needs to be equipped with properly calibrated radiation monitoring equipment, including survey meters and portable contamination monitors.

Equipment for dispensing radiopharmaceuticals needs to comply with relevant standards of the International Electrotechnical Commission or equivalent national standards.

Positioning devices such as supports and sandbags may be necessary for positioning animals. These materials need to be washable or need to be protected in such a way that decontamination procedures can be carried out. An example of positioning devices for use with horses is shown in Fig. 21.

Mobile or portable shielding equipment might be necessary for protection and safety of workers or to reduce background radiation in the gamma camera room for optimization of the image quality.
Fig. 21. A horse positioned in front of a gamma camera. The horse has cotton wool ear plugs and blinkers. Its head is resting on a height adjustable head stand to reduce movement artefacts as much as possible.

4.2.2.3. Security of sources

The objective of security of sources is to ensure continuity in the control of and accountability for each source at all times in order to meet the requirements of GSR Part 3 [2], para. 3.53.

In a veterinary nuclear medicine facility, the sources include unsealed sources include radiopharmaceuticals and as radionuclide generators, equipment for dispensing radiopharmaceuticals, and sealed sources used for calibration or quality control tests.

The International Organization for Standardization issues standards for the identification and documentation of unsealed sources [32]. Activities that are critical with regard to security of sources in a veterinary nuclear medicine facility include receipt of radiopharmaceuticals, storage of sources, movement of sources within the facility, and storage of radioactive waste [16].

The licensee of the veterinary nuclear medicine facility needs to develop procedures to ensure the safe receipt and movement of radioactive sources within the facility. The licensee
also needs to establish controls to prevent theft, loss and unauthorized withdrawal of radioactive materials, or the entrance of unauthorized personnel to controlled areas.

The licensee of the veterinary nuclear medicine facility is required to maintain an inventory of sources for which they are responsible, and procedures need to be put in place to check and confirm that the sources are in their assigned locations and are secure (GSR Part 3 [2], para. 3.53).

It is necessary to develop written procedures to stimulate proactive behaviour; for example, to prompt an investigation when a delivery of radiopharmaceuticals is not received at the expected time.

4.2.2.4. Maintenance of equipment

The proper functioning of equipment contributes to the efficacy of diagnostic procedures and therapeutic procedures. Maintenance and servicing of radiological equipment needs to be included in the quality assurance programme. Maintenance and servicing are usually performed by a trained engineer or technician employed either by a company offering such services (which may be the manufacturer and/or the vendor) or by the veterinary facility itself.

Maintenance programmes need to cover components of hardware and/or equipment, including their electrical and mechanical systems, as well as software components, including networks, databases and other software systems supporting the hardware.

Maintenance and servicing of equipment need to be completed at the intervals recommended by the manufacturer or by the regulatory body. While equipment is under servicing, it is not to be used for veterinary imaging until the service has been completed.

The engineer or technician needs to follow rules for radiation protection, rules for general health and safety, and procedures established by the employer, as well as the relevant rules and procedures of the veterinary radiation facility. Records of completed maintenance (preventive maintenance and corrective maintenance) and service records need to include a written report for each piece of equipment, describing the findings and any corrective actions necessary.
4.3. OCCUPATIONAL RADIATION PROTECTION IN VETERINARY MEDICINE USING UNSEALED SOURCES

4.3.1. General

In veterinary nuclear medicine, occupationally exposed workers are usually the veterinarians and veterinary technologists. Other veterinary professionals such as nurses and support staff participating in the management of animals to which radiopharmaceuticals have been administered, in particular in veterinary nuclear medicine facilities providing therapy services, are also subject to occupational exposure.

Workers in a veterinary nuclear medicine facility who are exposed to radiation from sources that are not required by or directly related to their work, such as administrative personnel and other service support personnel, are required to be afforded the same level of protection against such exposure as members of the public (see para. 3.78 of GSR Part 3 [2]).

4.3.2. Arrangements under the radiation protection programme

This subsection provides guidance specific to veterinary nuclear medicine. An IAEA Safety Guide [24] provides general and comprehensive recommendations and guidance on occupational radiation protection. This includes recommendations and guidance on radiation protection programmes, on assessment of occupational exposure and on providers of dosimetry services. These recommendations and guidance are applicable for all areas of use of radiation (including non-medical uses).

4.3.2.1. Classification of areas

Various areas and rooms in a veterinary nuclear medicine facility are required to be classified as controlled areas or supervised areas, in accordance with GSR Part 3 [2], paras 3.88–3.92. Once designated, these areas are subject to the requirements established in GSR Part 3 [2], paras 3.89–3.90 (for controlled areas) and 3.91–3.92 (for supervised areas).

These include requirements for: the delineation of areas; signage; protection and safety measures; control of access; provision of personal protective equipment; provision of individual monitoring and area monitoring; provision of equipment for monitoring for contamination; and provision of personal decontamination facilities.

All other rooms and areas that are not designated as controlled areas or supervised areas are considered to be in the public domain. Levels of radiation in these areas are required to be low enough to ensure compliance with the dose limits for public exposure.
Classification of areas in a veterinary nuclear medicine facility needs to be based on an analysis of all the processes used in their entirety, and not only on the location of equipment and radiation sources.

The following paragraphs give general guidance; final decisions by the licensee for a given veterinary radiation facility would generally be based on the advice of the radiation protection officer or a qualified expert in radiation protection.

The entrance to a scintigraphy room (controlled area) is shown in Fig. 22.

![Image of a scintigraphy room entrance](image)

*Fig. 22. The entrance to a scintigraphy room (controlled area). The door has the appropriate warning signs and is lockable. To the side of the door is a radiation monitor for monitoring for contamination on the feet and hands of personnel leaving the room.*

In a veterinary nuclear medicine facility, rooms for preparation of radiopharmaceuticals (i.e. radiopharmacies or ‘hot labs’), for injection of radiopharmaceuticals, and for storage and decay of radiopharmaceuticals need to meet the criteria for a controlled area and are required to be so designated.
Imaging rooms are also to be designated as controlled areas. This includes in particular those rooms housing equipment for dispensing radiopharmaceuticals (e.g. dispenser devices for radiopharmaceuticals, radioactive gases and radioactive aerosols used in positron emission tomography), as well as holding areas for animals that have been injected with radiopharmaceuticals (e.g. uptake rooms in a positron emission tomography facility). Rooms for animals undergoing therapy with radiopharmaceuticals are also to be designated as controlled areas.

Rooms housing hybrid machines that have an X ray component (single photon emission computed tomography–computed tomography and positron emission tomography–computed tomography) are also to be designated as controlled areas. There needs to be a warning light at the entrance to the room to prevent unintended entry while the X ray equipment is switched on.

Supervised areas may include examination rooms with probes, corridors and other areas where there are animals to which radiopharmaceuticals have been administered.

The area around the control panel of hybrid imaging equipment (e.g. positron emission tomography–computed tomography and single photon emission computed tomography–computed tomography) is to be classified as a supervised area. The radiation levels may be very low owing to shielding between the panel and the room containing the imaging equipment. However, classification of this area as a supervised area will ensure restricted access. Among other things, this will avoid distraction of the operator, which could lead to accidental or unintended exposure of animals.

Uncertainties about the extent of the designation of controlled areas and supervised areas need to be avoided. The boundaries of such areas, when possible, need to be the walls and doors or other physical barriers. These need to be clearly marked or identified with ‘radiation area’ signs.

4.3.2.2. Local rules and procedures in general

The local rules will encompass procedures relating to: ordering, transport and receipt of radiopharmaceuticals; unpacking, storage, preparation and administration of radiopharmaceuticals to the animals; examination or treatment of animals and care of treated animals; and storage and handling of associated radioactive waste.

Written local rules are to be established for a veterinary nuclear medicine facility for the purpose of ensuring protection and safety. These local rules need to include measures for the
optimization of protection and safety for occupational exposure, both in normal work and in abnormal conditions.

The local rules are to be readily accessible, for example on signs hung on doors giving access to certain parts of the controlled areas (e.g. the ‘hot lab’ or the imaging room). The local rules also need to cover the wearing, handling and storage of personal dosimeters. It is advisable to develop standard operating procedures for each procedure in veterinary nuclear medicine, and to make periodic reviews.

Equipment (hardware and software) is to be operated in a manner that ensures satisfactory performance at all times with regard to both the tasks to be accomplished and radiation protection and safety. The manufacturer’s operating manual is an important resource in this respect. Additional procedures may also be necessary to provide easy access to readily understandable information on the functioning of the equipment.

Staff in nuclear medicine need to understand the documented procedures for their work in the ‘hot lab’. This also applies in particular for the handling of radiopharmaceuticals; and for the operation of equipment (e.g. dose calibrator, contamination monitor) that they are using, including its safety features.

Staff need to be given adequate training, and periodic refresher training, to enable them to comply with the local rules and procedures, including procedures that deal with incidents that may lead to external or internal contamination, including dealing with spills of radioactive material. Additional training needs to be given when new radiopharmaceuticals or devices are to be used in the veterinary nuclear medicine facility.

These procedures are focused on minimizing external exposure as well as contamination; both their occurrence as well as their spread. All manipulation for dispensing radioactive material needs to be carried out over a drip tray and/or a plastic backed absorbent pad, for example.

Manipulation of unsealed sources is to be restricted to a minimum number of specifically designated work areas. Work with volatile radionuclides (e.g. $^{131}$I) needs to be performed under a fume hood or a similar ventilated device with appropriate filters to prevent contamination of the environment.

The preparation and dispensing of radiopharmaceuticals needs to be carried out behind a lead glass bench shield, using shielded vials and syringes, and using disposable gloves. Particular attention is to be paid to the handling of radionuclides in positron emission
tomography because of the higher emitted energy, which necessitates dedicated shielding material.

Food and drink, cosmetics, smoking materials, crockery and cutlery are not to be brought into areas where unsealed sources are used (animal feed may need to be radiolabelled for animal studies, however). Food or drink is not to be stored in a refrigerator used for the storage of unsealed sources.

Personal cell phones are not to be used in these controlled areas. Handkerchiefs are also not to be used in controlled areas: an adequate supply of paper tissues needs to be provided. Protective clothing is to be worn in controlled areas.

4.3.2.3. Local rules and procedures for the ‘hot lab’: preparation of radiopharmaceuticals

Packaging and containers for radioactive material need to be checked for contamination on opening. If a package containing radioactive sources is damaged upon arrival, a survey of removable contamination and the external radiation field needs to be carried out.

Syringes used for handling radioactive liquids need to be appropriately shielded wherever practicable. Needles need to be recapped during work with radioactive liquids, to maintain containment. Pipettes are never to be operated by mouth. The work area needs to be kept tidy and free from articles not required for work.

A monitoring and cleaning programme needs to be established to ensure minimal spread of contamination. Cleaning and decontamination can be simplified by covering benches and drip trays with disposable material such as plastic backed absorbent paper. Various materials can be used for shielding purposes, such as lead, tungsten, lead glass and lead composite.

Shielding incorporating acrylic is usually more suitable for beta emitters, as it lowers the amount of bremsstrahlung produced. Lead needs to be coated to provide a cleanable surface. Glassware and implements for use in the radiopharmacy need to be appropriately marked and under no circumstances are to be removed from the radiopharmacy.

Containers such as lead pots that no longer contain radioactive material may be dealt with as conventional (non-radioactive) waste. Any radiation warning labels need to be removed or obliterated before clearance of (i.e. removal of regulatory control from) the containers.

Figure 23 shows a ‘hot lab’ in a veterinary nuclear medicine facility.
Fig. 23: A ‘hot lab’ in a veterinary nuclear medicine facility. Manipulation of radioactive material is performed in a fume hood. L-block shielding is present. Note the filter system for trapping airborne radioactive material to the right side of the fume hood. Use of a filter system is mandatory in using volatile radionuclides such as radioiodine. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

4.3.2.4. Local rules and procedures for injection and scanning of animals

Injection of animals is usually performed intravenously, preferably via a preplaced catheter or else by direct needle placement. A leaen shielded syringe is preferable unless this hampers injection to an undesirable degree. Protective clothing is unlikely to be necessary for persons accompanying animals into gamma camera rooms. An exception is the scanning of horses, for which it might be beneficial for the animal handler to wear a lead apron [33, 34].

Before injection, the horse’s legs and feet are protected with bandages and tape to prevent contamination of its legs and feet and of the floor (see Figs 24 and 25). The bandages and tape will be removed outside the stable prior to the scanning procedure. Animals are sedated for image acquisition unless their condition poses a risk. Sedation is sometimes not necessary for very short procedures (e.g. thyroid scans or kidney scans).

When contamination (usually contamination by urine) occurs, remedial actions will depend on the amount spilled. Specific procedures are described under the heading ‘spillage of radioactive material’. To prevent contamination by horse urine, labelled buckets, ideally with long handles, need to be available for collecting the urine (see Fig. 26).
A horse’s foot in a plastic bag after injection of the radionuclide. The bag is a used bag for intravenous fluid. Bags are used to cover the horse’s feet to avoid radioactive contamination of the ground by urine between the stable and the scintigraphy room. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

Wood shavings are used as bedding in the stable to absorb the urine of horses. Bandaging horses’ legs and covering the feet with tape reduces radioactive contamination of the horse’s legs by urine. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

On leaving the controlled area, workers need to place protective clothing that is contaminated into an appropriate container. The method of removing gloves needs to be based on the technique for surgical gloves so as to avoid transferring radioactive material to the hands.

Attenuation by lead aprons at the gamma energies typically used in veterinary nuclear medicine is modest; it is even less for protective aprons that are not lead based. The use of automatic dispensers and injectors and mobile shields offers more effective ways to reduce the exposure of the operator.
Operators, animal handlers and, where necessary, animal owners need to be as far as possible from the animal during the acquisition of images. In this regard, the animal can be sedated and/or anaesthetized for the imaging procedure when possible and when safe for the animal. For imaging of large animals, the nature of the animal needs to be considered and conventional safety as well as radiation protection has to be taken into account. However, the number of animal handlers involved needs to be limited as far as is safely possible.

All containers used for radioactive material need to be clearly labelled, indicating the radionuclide, chemical form and activity at a given date and time. Batch number and expiry date and time need to be included as appropriate. All such containers are to be adequately sealed and shielded at all times. Containers are not to be handled directly, except for very small activities. If possible, tongs or forceps need to be used for vials and syringe shields need to be used. Records have to be kept of stocks, administrations and management of radioactive waste.

Staff leaving a controlled area need, after removal of their protective clothing, to wash their hands and then monitor their hands, clothing and body. Liquid soap needs to be provided unless considerations of aseptic conditions necessitate an alternative cleaner. Non-abrasive nail brushes are to be used only if contamination persists after simple washing.

Spread of contamination by a horse on its way from the stable to the scanning room can be minimized by the use of leg covers in the stable. These are to be removed when the horse leaves the stable (see Figs 24 and 25). Clearly labelled buckets on long handles can be used to catch urine during transit of the horse between the stable and the scanning room, and in the scanning room (see Fig. 26).
Fig. 26. A horse being led from its stable to the scintigraphy room. To avoid contamination of the ground, the horse’s urine is caught in a bucket with a long handle.

4.3.2.5. Specific local rules and procedures for therapy with radiopharmaceuticals

Administration of radiopharmaceuticals is usually by the oral route, by intravenous injection (systemic), by subcutaneous injection and intra-arterial injection (locoregional), or by instillation into closed joints (intra-articular: radiosynoviorthesis) or body cavities (intracavitary).

Appropriate (depending on the decay mode of the radionuclide) shielding of syringes is necessary during the administration of radiopharmaceuticals to ensure that the doses to extremities for the operator are kept below occupational dose constraints. For some therapies, it is advisable to wear other protective equipment (e.g. gloves, shoe covers or step-off-pads).

For oral administrations of therapeutic radiopharmaceuticals, the radioactive material needs to be placed in a shielded, spill proof container. Care needs to be taken to minimize the chance for splashing of liquid or for dropping of capsules.

Care of animals to which radiopharmaceuticals have been administered needs to be carried out by animal handlers trained in radiation protection and in the particular demands of the specific therapy. Clear instructions need to be provided in the form of standard operating procedures and orally. The training needs to cover radiation protection and specific local rules, in particular for situations in which there is a risk of contamination from urine, faeces or vomit.
The construction of the rooms and stables need to follow same guidelines as for other parts of the controlled area. Floors and ceilings need to be washable and resistant to chemical change, and need to be curved to the walls, with all joints sealed and glued to the floor. Plastic backed absorbent paper needs to be laid on the floor to reduce the spread of contamination.

It is good practice for the floors of rooms and stables for animals to which radiopharmaceuticals have been administered to be covered with absorbent material as bedding. Materials such as wood shavings can be used to absorb contaminated urine. Such rooms and stables would not be cleaned until all radionuclides present had decayed sufficiently (see Fig. 25).

Non-essential animal care needs to be minimized to reduce the dose to animal handlers, operators and veterinarians. For example, additional testing or treatment could, where practicable, be performed prior to the administration of radiopharmaceuticals or could be delayed until the radiopharmaceuticals have decayed.

Procedures need to be developed for the handling of any potentially contaminated item. When an animal needs intensive care, the advice of the radiation protection officer needs to be obtained. While urgent care of the animal is a priority and need not be delayed, it may be necessary to restrict the amount of time that a veterinarian spends with the animal. It may be necessary to have a risk assessment carried out by a qualified expert in radiation protection.

Access to the animal to which radiopharmaceuticals have been administered needs to be restricted to veterinarians and handlers directly involved in the procedure, who need to be clearly informed of the radiation risks. Protective clothing, such as laboratory coats, gloves and shoe covers, are to be provided at the entrance to the wards and stables. When leaving the wards and stables, the protective clothing need to be removed, bagged and stored until radioactive material has decayed.

The dose rate from the animal needs to be measured prior to release to assure meeting the regulatory release criteria. Animals can be released when dose rates or activity concentration reaches criteria for exposure to the public established by the regulatory body. Risk assessment can be performed to address the presence in the household of small children or of women who are pregnant or are breast-feeding.

It may be necessary to delay the release of the animal from the veterinary facility or to issue special instructions for conditions when it is released. The owner of the animal is to be provided with clear instructions both orally and in writing at the time of the release of the
animal from the veterinary facility. An example of such instructions can be found in Appendix II.

4.3.2.6. **Decontamination of persons**

Hands are to be washed on completing work with unsealed sources and on leaving a controlled area, because of possible contamination. If detectable contamination remains on the hands after simple washing, the use of a surfactant or chelating agent specific to the chemical form of the contaminant may be more successful.

Guidance for monitoring the level of contamination needs to be provided. A decontamination kit and procedures for its use need to be available in the veterinary nuclear medicine facility [31].

The radiation protection officer needs to be consulted when contamination of parts of the body other than the hands is suspected, or when the procedures for decontamination of the hands are ineffective. Special care needs to be taken in decontamination of the face to restrict entry of radioactive material into the eyes, nose or mouth.

If the skin is broken or if a wound is sustained under conditions where there is a risk of radioactive contamination, the injury needs to be irrigated with water as soon as appropriate. Care has to be taken not to wash contamination into the wound. As soon as first aid measures have been taken, the injured person needs to seek further treatment, including decontamination if necessary. The radiation protection officer is to be consulted as necessary.

Contaminated clothing needs to be removed as soon as practicable, and care needs to be taken not to spread contamination.

All staff working with unsealed sources or with animals to which radiopharmaceuticals have been administered need to be trained in the procedures for dealing with accidents, spills or contaminated persons, with refresher training at appropriate intervals. This includes instructions on appropriate washing, showering and eye washing.

Guidance for monitoring the contamination level needs to be available. A decontamination kit and procedures for its use is to be available on site. Further information is provided in Appendix III.

4.3.2.7. **Personal protective equipment and in-room protective devices**

In a veterinary nuclear medicine facility, protective equipment includes the following:
(a) Shields for bench tops, vials, syringes and activity meters, and for the preparation of radiopharmaceuticals (i.e. L-blocks and side blocks) of a material and thickness appropriate to the type and energy of the radiation (see Fig. 27).

(b) Protective clothing to be worn in work areas where there is a likelihood of contamination, such as areas for the preparation and administration of radiopharmaceuticals. Protective clothing may include laboratory gowns or overalls, waterproof gloves (made of latex or non-latex material such as neoprene, polyvinyl chloride or nitrile), overshoes, and caps and masks for aseptic work. The clothing serves both to protect the body of the wearer and to help prevent the transfer of contamination to other areas. The clothing needs to be monitored and needs to be removed before leaving designated areas (see Fig. 28). It is good practice to change gloves after each manipulation.

(c) Lead aprons to be worn for entering a room with hybrid imaging (e.g. positron emission tomography–computed tomography) if X rays are about to be used and if either a staff member or the animal owner needs to be in the room with the animal. Lead aprons may also be worn when preparing and administering $^{99m}$Tc, although their use is not advisable and protective measures such as mobile shields are more effective. Lead aprons may be beneficial in equine scintigraphy (see Figs 16 and 29) [33, 34].

(d) Tools for remote handling of radioactive material, including tongs and forceps.

(e) Containers for radioactive waste and for transport of radioactive sources.
Fig. 27. Detail of the working space in a fume hood. The surface of the working space is covered with plastic backed absorbent paper. Note the dose calibrator to the left of the L-block shielding. A lead shielded syringe carrier is present to the right, and on the working space of the L-block shield there is a lead syringe and bottle shield. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)

Fig. 28. Entrance to and exit from the scintigraphy unit. Note the coat racks. The rack on the right is reserved for aprons worn outside the unit, the rack on the left for those worn in the unit. A Geiger–Müller counter is present for checking contamination of persons performing investigations or interventions in the unit. (Courtesy of: Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University, Belgium.)
Fig. 29. An operator on her way from the ‘hot lab’ to the stable to inject a horse. She is wearing protective clothing, goggles and gloves and is transporting the radiopharmaceutical ($^{99m}$Tc) in a lead lined box. (Courtesy: ??)

4.3.2.8. Monitoring of the workplace

Workplace monitoring for radiation exposure is necessary to ensure protection and safety, and it is used to minimize exposure to workers. Workplace monitoring needs to be performed and records maintained as part of the veterinary nuclear medicine facility’s radiation protection programme (Ref. [2], paras 3.96–3.101). The facility’s radiation protection officer or qualified expert needs to provide specific advice on the workplace monitoring programme, including advice on any investigations that arise through investigation levels being exceeded.

Workplace monitoring comprises the making of measurements in the working environment and interpretation of the results. Workplace monitoring serves several purposes, including routine monitoring; special monitoring for specific occasions, activities or tasks; and confirmatory monitoring to check assumptions made about exposure conditions.

Workplace monitoring can be used to verify the occupational exposures of workers whose work involves exposure to radiation at predictable low levels. It is especially important for staff members who do not have individual monitoring.

In the veterinary nuclear medicine facility, workplace monitoring covers both external exposure and contamination.
Monitoring for contamination is necessary for:

(a) All working surfaces (including the interior of enclosures), tools, equipment and devices (including dosimetry systems, computers and peripherals, and stress testing units), the floor and any items removed from these areas;

(b) Contained workstations, ventilation systems and drains during maintenance;

(c) Protective clothing and personal clothing, and shoes, in particular when leaving a controlled area that is controlled because of the risk of contamination (monitors need to be available near the exit);

(d) Bedding used for animals to which radiopharmaceuticals have been administered;

(e) Additional monitoring of animals that may be necessary to minimize contamination of the workplace.

Periodic monitoring with a survey meter and contamination monitor or by wipe tests needs to be conducted for controlled areas, in particular when contamination is suspected.

4.3.3. Assessment of occupational exposure

GSR Part 3 requires that individual monitoring be undertaken where appropriate, adequate and feasible for any worker who usually works in a controlled area, or any worker who occasionally works in a controlled area and may receive a significant dose from occupational exposure (Ref. [2], paras 3.99–3.102). The dose limits for occupational exposure and for public exposure are presented in Table 1.

Workers for whom individual monitoring may be required include: professionals in veterinary nuclear medicine and veterinary radiation technologists; the radiation protection officer; and pharmacists for radiopharmaceuticals. They also include: any other persons involved in the preparation, dispensing and administration to animals of radiopharmaceuticals for diagnosis and therapy; staff dealing with radioactive waste; and any nursing staff or other staff who work in controlled areas or who deal with animals to which radiopharmaceuticals have been administered.

Personal dosimeters are assigned to individuals for use during procedures in a particular facility. Personal dosimeters are not to be shared with other staff and are not to be worn in other facilities. For example, if an employee is issued with a dosimeter at a particular veterinary facility, it is to be worn at that veterinary facility only and not at any other veterinary facilities where he or she may also work.
The monitoring period (i.e. period of use of a dosimeter) specified by regulatory bodies in most States is typically in the range of one to three months. The monitoring period is determined by such factors as availability of service, work load and type of work.

A one month monitoring period is usually used for persons performing procedures associated with higher levels of occupational exposure. A longer monitoring period (two or three months) is more typical for personnel exposed at lower levels. A one month monitoring period would usually mean that the actual dose from occupational exposure is lower than the minimum detection level of the dosimeter, resulting in there being no detectable doses.

With a longer monitoring period, it is more likely that a reading can be obtained. In certain circumstances (e.g. the introduction of new procedures, or work at high dose rates), shorter monitoring periods may be necessary. In such situations, the supplementary use of electronic dosimeters may be appropriate.

Unnecessary delays in the return of, reading of and reporting of doses recorded on dosimeters are to be avoided. Dosimeters need to be sent from the veterinary nuclear medicine facility to the dosimetry service provider, which would then process the dosimeters and return the dose reports, all in a timely manner. Some regulatory bodies may specify a performance criterion for timely reporting.

When a protective apron is being used specifically in examinations of horses, the assessment of effective dose may not be straightforward:

(a) A single dosimeter placed under the protective apron, reported in \( H_p(10) \), provides a good estimate of the contribution to the effective dose of the parts of the body protected by the apron, but underestimates the contribution of the unprotected parts of the body (the thyroid, the head and neck, and the extremities).

(b) A single dosimeter worn outside the protective apron, reported in \( H_p(10) \), provides a significant overestimate of the effective dose which needs to be corrected for the protection afforded by the apron by using an appropriate algorithm [35–37].

(c) In veterinary nuclear medicine, a single dosimeter placed under the protective apron provides an estimate of the effective dose that is sufficient for radiation protection purposes.

In veterinary nuclear medicine, certain workers may be at risk of both surface (skin) contamination and internal contamination by ingestion, inhalation or adsorption of radioactive
material. This necessitates programmes of both external and internal monitoring. Employers are required to ensure that workers who could be subject to exposure due to contamination are identified (GSR Part 3 [2], para. 3.102) and for arranging for appropriate monitoring [24].

When not in use, individual dosimeters need to be kept in a dedicated place and need to be protected from damage and from irradiation. If an individual loses his or her dosimeter, the individual needs to inform the radiation protection officer, who needs to perform a dose assessment, record this evaluation of the dose and add it to the individual’s dose record.

Where there is a national dose registry, information on the dose estimate needs to be provided in a timely manner. The most reliable method for estimating an individual’s dose is to use his or her recent dose history. In those cases where the individual performs non-routine types of work, it may be better to use as the basis for the dose estimate the doses of co-workers having similar exposure conditions.

Additional direct reading operational dosimeters, such as electronic dosimeters, may be considered for use in a veterinary nuclear medicine facility, e.g. in a new facility or with the introduction of new procedures. Such devices can give workers an instant indication of both the cumulative dose and the current dose rate and may also allow the setting of an alarm for when a given level of dose has been reached [24].

4.3.3.1. Investigation levels for workers

Investigation levels are different from dose constraints and dose limits; they are used to provide a warning of the need to review procedures and performance, to investigate what is not working as expected and to take timely corrective action. Corrective actions need to be carried out when the dose received by a worker exceeds an investigation level.

In veterinary nuclear medicine, predetermined values such as 0.5 mSv per month for effective dose or 15 mSv per month for finger dose could be used as investigation levels. Suitable alternative investigation levels may be doses that exceed an appropriate fraction (e.g. 25%), pro rata per monitoring period, of the annual dose limits or doses that exceed a preset value above a historical average.

Abnormal conditions and/or events also need to trigger an investigation. In all cases the investigation needs to be carried out for the purpose of optimization of protection and safety for occupational exposure.
Investigation levels also need to be set for workplace monitoring, with account taken of exposure scenarios and the predetermined values adopted for investigation levels for workers. Further details on investigation levels are provided in Ref. [24].

An investigation needs to be initiated as soon as possible following a trigger or an event. A written report needs to be prepared concerning the cause, the determination or the verification of the doses received by workers, any corrective actions taken, and any instructions or recommendations necessary to avoid a recurrence. Such reports are to be reviewed by the licensee. In some cases, the regulatory body may also need to be informed.

4.3.3.2. Records of occupational exposure

Records of occupational exposure for each worker are to be maintained during and after the worker’s working life, at least until the worker attains or would have attained the age of 75 years and for not less than 30 years after cessation of the work in which the worker was subject to occupational exposure.

Apart from demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary facility for other purposes. These include assessing the effectiveness of the optimization of protection and safety at the facility and evaluating trends in exposure.

National or local regulatory bodies might specify additional requirements for records of occupational exposure and for access to the information contained in the records. Employers are required to provide workers with access to records of their own occupational exposure (GSR Part 3 [2], para. 3.106(a)). Further general guidance on records of occupational exposure is given in Ref. [24].

4.3.4. Conditions of service and special arrangements

As required in GSR Part 3 [2], para. 3.111, special compensatory arrangements, or preferential consideration with respect to salary, special insurance coverage, working hours, length of vacation, additional holidays or retirement benefits, are neither to be granted nor to be used as substitutes for measures for protection and safety in accordance with the requirements of GSR Part 3.

4.3.4.1. Female workers who are pregnant or breast-feeding

It cannot in GSR Part 3 [2] be made a requirement on a female worker to notify an employer of a suspected pregnancy or of breast-feeding. However, it is necessary to ensure that
all female workers understand the importance of making such notifications so that their working conditions may be modified accordingly (Ref. [2], para. 3.113).

GSR Part 3 [2] establishes requirements for employers, in cooperation with registrants and licensees, to provide female workers who are liable to enter controlled areas or supervised areas or who may undertake emergency duties with appropriate information in this regard (GSR Part 3 [2], para. 3.113(b)).

The employer of a female worker, who has been notified by the female worker of her suspected pregnancy or that she is breast-feeding, is required to adapt her working conditions in respect of occupational exposure so as to ensure that the embryo or fetus or the breastfed infant is afforded the same broad level of protection as is required for members of the public (GSR Part 3 [2], para. 3.114).

The limitation of the dose to the embryo or fetus does not mean that a female worker who is pregnant is required to avoid work with radiation. The employer is, though, required to carefully review the working conditions with regard to both exposure and potential exposure for female workers who have notified their employer of their suspected pregnancy.

For example, a female worker who is pregnant may be restricted from spending time in the radiopharmacy or working with radioiodine solutions [38], which could cross the placental barrier and concentrate in the fetal thyroid.

A possible adaptation is the reassignment of a female worker who is pregnant to duties where the likelihood of an accident or incident is lower or to a location that may have a lower ambient dose equivalent. Such reassignments need to be accompanied by adequate training. A further consideration is the need to avoid including a female worker who is pregnant in the response to an accident such as a radioactive spill.

4.3.4.2. Persons under 18 years of age

In many States there is the possibility that students of age 16 years or more, but under the age of 18 years, who are undertaking studies and training to become a veterinary technologist may be subject to exposure. GSR Part 3 [2], para. 3.116, establishes requirements on access to controlled areas for persons under the age of 18 years, and the dose limits are more restrictive; see Table 1.
4.3.5. **Education, information, instruction and training**

General guidance regarding education and training of veterinary professionals is presented in Section 2.5. The following guidance is additional guidance that is applicable to veterinary professionals working in diagnostic radiology and interventional radiology.

The objectives of the training include imparting knowledge of risks associated with radiation and mechanisms of risk reduction as well as training for operating specific equipment used for diagnostic imaging and interventional radiology in the veterinary facility, and for performing specific procedures. Equipment specific training is usually provided by the applications specialist of the manufacturer, externally or in-house by a suitably qualified trainer and augmented by use of the equipment manual. Descriptions of best practice procedures can also be found in the scientific literature.

An example of the education and training in radiation protection for veterinary professionals are those developed by the Heads of European Radiological Protection Competent Authorities (HERCA) [17]. The HERCA guidelines are included as an Annex. The HERCA guidelines include Table A-1 Core Learning Outcomes in Radiation Protection for Veterinary Doctors and Table A-24 Additional Learning Outcomes for Veterinary Doctors working in the Field of Nuclear Medicine that contain the knowledge, skills and competencies for veterinary practitioners.

The HERCA guidelines also include Table A-5 Core Learning Outcomes in Radiation Protection for Veterinary Radiographers and Veterinary Assistants and Table A-6 Additional Learning Outcomes for Veterinary Radiographers and Veterinary Assistants working in the Field of Nuclear Medicine that contain the knowledge, skills and competencies for veterinary technologists.

HERCA note that the education and training requirements need to be met before veterinary professionals start work with radiation. HERCA also note that veterinary radiographers and veterinary assistance do not have to meet all the requirements set out in the document, depending on the scope of practice and the degree of autonomy that they are permitted in their country.

Veterinary practitioners need to be given the responsibility to provide information, instruction and training to other staff in the veterinary facility. These staff include veterinary nurses and animal handlers who may be required to assist in the performance of nuclear
medicine procedures, participate in the management of animals to which radiopharmaceuticals have been administered, and clean the rooms and stables after the animals to which radiopharmaceuticals have been administered have left the veterinary facility. Other staff may need to be provided with information on the areas with restricted access, and on general safety issues.

Veterinary practitioners need to be given responsibility for providing appropriate information to animal owners on the procedures that are carried out on their animal, and to provide instructions for those owners that are allowed to manage at home their animals to which radiopharmaceuticals have been administered. An example of such instructions is provided in Appendix II.

4.4. RADIATION PROTECTION OF THE PUBLIC

4.4.1. General

Public exposure may arise from the performance of veterinary nuclear medicine for persons in and around the veterinary nuclear medicine facility, for the owners of animals (e.g. pet owners) and also in the wider public domain. The last can occur as a result of the release from the veterinary nuclear medicine facility of animals with some remaining radioactive material.

Persons who may be so exposed are visitors to the facility, including the owners of animals; and the wider public. In addition, there is a possibility, albeit low, of public exposure via exposure pathways associated with the management of radioactive waste.

4.4.2. Animal owners and other visitors

Access by visitors to rooms at the veterinary nuclear medicine facility is restricted to persons who are accompanied by staff members. These need to be staff members who are involved in procedures performed at the particular facilities and informed about the relevant issues in and measures for radiation protection. Signs, conspicuously positioned, need to be used at the entrances of controlled areas to prevent inadvertent entry. For controlled areas, GSR Part 3 [2] requires the use of the trefoil symbol specified by the International Organization for Standardization [18].
4.4.2.1. Animal owners and/or the general public

The animal owner is not to be present when the animal is undergoing procedures in veterinary nuclear medicine. Instructions to pet owners with regard to public exposure and the release of animals are provided in Appendix II.

The radiation protection officer of the veterinary nuclear medicine facility, in consultation with the regulatory body, needs to establish rules with regard to public exposure following the release of an animal that has undergone therapy with radiopharmaceuticals.

It is required [2] that any such public exposures will be below the dose limit for public exposure and, preferably, lower than any applicable dose constraint. Owners of animals need to be provided with detailed information and instructions concerning the precautions to be taken in order to keep exposures for themselves, family members and other members of the public below the dose limits for public exposure.

In particular, the instructions need to cover the management of radioactive waste following the release of an animal after the use of radionuclides for diagnostics and therapy. For cats, contaminated cat litter needs to be kept in a separate place, for a period of a time that will depend on the radionuclide.

For dogs, voiding and defecation needs to be limited to places where close contact with the public is as limited as possible (i.e. not in dog parks or in other public places).

For horses, information needs to be provided regarding contact with the horse in the stable and the disposal of bedding from the stable as radioactive waste. The owners of horses need to be provided with detailed information and instructions concerning the precautions to be taken at home in order to keep exposures for themselves, family members and other members of the public below the dose limits for public exposure.

4.4.3. Monitoring and reporting

GSR Part 3 [2], Requirement 32 and para. 3.137, establishes requirements to be met by the licensee of the veterinary nuclear medicine facility with respect to monitoring and reporting. In the veterinary nuclear medicine facility, procedures are required to be in place to ensure that:

(a) The requirements regarding public exposure are complied with and such exposure is assessed;
(b) The requirements regarding discharge of radionuclides to the environment are complied with;

(c) Appropriate records are kept of the results of the monitoring programmes.

The programme for monitoring of public exposure arising from veterinary nuclear medicine needs to include dose assessment in the areas in and surrounding the veterinary nuclear medicine facility that are accessible to the public. Estimated doses can be derived from the shielding calculations in the planning stage, and combined with results from area monitoring and contamination monitoring at the initial operation of the facility and periodically thereafter.

Records of dose assessments need to be kept for a period that meets any relevant regulatory requirements. In the absence of such requirements, a suggested period of time for keeping such records is 7–10 years. The dose limits for public exposure are set out in Table 1.

4.5. PREVENTION OF ACCIDENTS AND MITIGATION OF THEIR CONSEQUENCES

4.5.1. Safety assessment

The registrant or licensee needs to conduct a safety assessment applied to all stages of the design and operation of the veterinary nuclear medicine facility. A report on the safety assessment is to be submitted to the regulatory body if so required. The safety assessment needs to deal with determining what can go wrong and how it can be prevented, and, in case it does occur, how it can be mitigated.

Safety assessments in veterinary nuclear medicine include consideration of all the steps in the use of radiopharmaceuticals for diagnosis and treatment at the facility. The steps include ordering, transport and receipt of radiopharmaceuticals; unpacking, storage, preparation and administration of radiopharmaceuticals to the animals; examination or treatment of animals; care of treated animals; and storage and handling of radioactive waste.

On the basis of events identified in the safety assessment for the veterinary nuclear medicine facility, procedures for mitigatory actions need to be prepared for events associated with potential exposure. These procedures need to include the allocation of responsibilities and resources, the development and adoption of procedures, and the provision of training and periodic retraining of the relevant staff in executing mitigatory actions.

If the safety assessment indicates that there is a reasonable likelihood of an emergency affecting either workers or members of the public, the registrant or licensee is required to
prepare an emergency plan in consultation with a qualified expert. Emergency arrangements and procedures commensurate with the hazards assessed and the potential consequences of accidents and incidents need to be established, as appropriate.

4.5.2. **Prevention of accidents**

Accident prevention is the best means for avoiding potential exposure. GSR Part 3 [2], paras 3.39–3.42, establishes requirements for good engineering practice, defence in depth and facility based arrangements to achieve this. Design considerations for the veterinary nuclear medicine facility and its equipment are described in Section 4.2.

(a) Measures for defence in depth are necessary to cope with events identified in the safety assessment and in the evaluation of the reliability of safety systems (including administrative procedures and operational procedures, and design of the facility and of equipment. For example, theft of sources can be minimized through multiple layers of security, including having sources locked up in a locked room, in an area that has restricted access.

(b) Operational experience and lessons learned from accidents and from errors provide valuable information. This information needs to be incorporated into the programmes for training, maintenance and quality assurance.

4.5.3. **Mitigation of the consequences of accidents**

As stated in GSR Part 3 [2], if an event or a sequence of events that has been considered in the assessment of risks (safety assessment) does actually occur, it may be treated either as a planned operation or, if an emergency has been declared, as an emergency.

Procedures for mitigatory actions in a veterinary nuclear medicine facility cover, but are not be limited to the following:

(a) Incidents and accidents, including those of low probability, and actions to deal with them;
(b) The persons responsible for taking actions, with full contact details;
(c) The responsibilities of individual personnel in implementing mitigation and emergency procedures;
(d) Equipment and tools necessary to take the mitigatory actions and to follow the emergency procedures;
(e) Training and periodic exercises;
(f) Recording and reporting systems;
(g) Immediate measures to avoid unnecessary radiation exposures of staff and the public;
(h) Measures to prevent access of persons to areas affected;
(i) Measures to prevent spread of contamination, including leakage from fume hoods and ventilation systems.

Kits need to be kept readily available for taking mitigatory actions and following emergency procedures. These kits may include the following:

(a) Protective clothing, for example overshoes and gloves;
(b) Materials for decontamination of the areas affected, including absorbent materials for wiping up spills;
(c) Materials for decontamination of persons;
(d) Warning notices and barrier tape;
(e) Portable monitoring equipment;
(f) Bags for waste, tape, labels and pencils.

Workers involved in such events in veterinary nuclear medicine or workers engaged in emergency procedures are required to be protected against occupational exposure within the dose limits for occupational exposure in planned situations of exposure.

However, if it is considered justified in an emergency for these dose limits to be exceeded, emergency workers are required to be protected consistently with the requirements [2, 39] and the recommendations and guidance [24] for emergencies.

4.5.3.1. Damage to radionuclide generators

Radionuclide generators, such as generators for $^{82}$Rb, $^{99m}$Tc and $^{68}$Ga, have relatively high levels of activity. In the event of a generator being damaged, the mitigatory actions that need to be taken include:

(a) Evacuate the area immediately and take measures to prevent entry to the area.
(b) Inform the radiation protection officer. The radiation protection officer needs to confirm the spillage, specify the safety boundaries, and supervise procedures for decontamination and monitoring, including determining when restrictions to enter the area can be lifted.
(c) Record details of the event and make a report to the relevant regulatory body.

4.5.3.2. Spillage of radioactive material

Procedures for dealing with spillage of radioactive material and with decontamination of persons are provided in Appendix III.
4.5.3.3. Need for urgent veterinary attention to animals to which therapeutic radiopharmaceuticals have been administered

There may be veterinary emergencies that necessitate the immediate care of animals to which radiopharmaceuticals have been administered in therapy. In such cases, dose rates near animals can be high.

Measures need to be taken to minimize exposure of the staff attending the animals. All staff members need to wear impermeable protective gloves and need to be informed on and trained in how to deal with such situations. Exercises of the procedures need to be held periodically.

Considerations of radiation protection need not prevent or delay life saving operations on an animal in the event that surgery is necessary. The following precautions need to be observed:

(a) Notify and inform the operating room staff of the circumstances.
(b) Modify operating procedures under the supervision of the radiation protection officer to minimize exposure and the spread of contamination.
(c) Use protective equipment provided that efficiency and speed of action are not affected.
(d) Rotate personnel as necessary if the surgical procedure is lengthy.
(e) Determine the exposures of the people involved in the procedure.

4.5.3.4. Lost sources

It is critical that an inventory of sources is kept up to date. It can then be determined immediately whether a source is (or sources are) missing and which, what its type and activity are, when and where it was last known to be, and who last took possession of it. A proactive attitude is important for the case that sources are ordered and not received at the expected time. Making a check for the arrival of a source at the expected time of receipt needs to be part of the procedures. The actions to be part of the contingency plans include:

(a) Obtain assistance from the radiation protection officer.
(b) Conduct a local search.
(c) Check and ensure security and control of other sources.
(d) Check all possibilities in the veterinary facility.
(e) If the source is not found, call the company and inform them of the failure so that they can trace the shipment and find out where the source is.
(f) If the source is still not found, report the loss of the source according to the rules given
by the regulatory body.

4.5.3.5. *Fires, earthquakes and other external events affecting the veterinary nuclear medicine facility*

The usual facility drill needs to be observed. This needs to provide for safe evacuation of visitors and staff, and, when possible, animals. When the first responders (for example, the fire services) attend, they need to be informed of the presence of radioactive material.

No one, other than emergency responders, may re-enter the building until it has been checked for contamination by the RPO or by the radiation safety staff of the agency in charge of emergency response. Requirements are established and recommendations and guidance on the arrangements to deal with such emergencies are provided in Refs [39] and [40].

4.6. **SAFETY IN THE TRANSPORT OF RADIOACTIVE MATERIAL**

GSR Part 3 [2], para. 2.25 establishes requirements on the transport of radioactive material, invoking in particular the IAEA Regulations for the Safe Transport of Radioactive Material, SSR-6 [15].

The Transport Regulations use the defined terms ‘consignor’ to mean any person, organization or government that prepares a consignment for transport, and ‘consignee’ to mean any person, organization or government that is entitled to take delivery of a consignment. ‘Consignment’ is also a defined term, meaning any package or packages, or load of radioactive material, presented by a consignor for transport.

The licensee of a veterinary nuclear medicine facility may be both a consignee and a consignor, and hence may have responsibilities for both the receipt and the shipment of radioactive material. Receipt of radioactive material will be a regular occurrence for all veterinary nuclear medicine facilities. Shipments may take place when expired radiation generators, old sealed calibration sources or radioactive liquids (for example $^{14}$C solutions) need to be returned to the supplier or disposed of off the site, as applicable.

Detailed requirements for the safe transport of radioactive material — including general provisions; activity limits and classification; requirements and controls for transport; requirements for radioactive material and for packagings and packages; test procedures; and approval and administrative requirements — are established in Ref. [15].
Emergency arrangements for the transport of radioactive material need to be put in place, in line with the requirements of GSR Part 7 [39] and the requirements and guidelines of the regulatory body.

The licensee and the radiation protection officer of the veterinary nuclear medicine facility need to be familiar with these requirements and regulations to ensure that the transport of radioactive material for which they are responsible complies with the requirements and regulations.

5. RADIATION PROTECTION AND SAFETY IN VETERINARY RADIATION THERAPY

5.1. GENERAL

Veterinary radiation therapy is the branch of veterinary oncology that uses ionizing radiation (teletherapy and brachytherapy), either alone or in combination with other modalities, for the treatment of animals with malignancies or other diseases. Treatment using unsealed sources is covered in Section 4.

Imaging studies used in the preparation, planning, verification and delivery of treatment are covered in Section 3. The following guidance is similar to what is typically provided for a facility in which people undergo radiation therapy [19]. Guidance specific to veterinary use is also provided in this Safety Report, where appropriate.

In applications of veterinary medicine, radiation therapy equipment and sources can be only used and operated under the direct authority of veterinarians who are properly trained and credentialed to perform or to delegate such work [18].

Radiation therapy equipment for use in veterinary medicine can be bought new from manufacturers or second-hand from brokers or directly from human radiotherapy facilities, in order to reduce installation costs. Such equipment needs to meet veterinary standards of care for as long as it is performing adequately and being maintained and serviced regularly and as required. Unlike equipment in veterinary radiology, there is currently no radiotherapy equipment designed and manufactured for veterinary use.

External beam radiation therapy (teletherapy) is usually performed with linear particle accelerators producing high energy (MV) photon or electron beams. Cobalt-60 units are going out of use in many countries. Superficial and orthovoltage units, producing low and medium energy X rays (kV), are also found in veterinary medicine.
External beam radiation therapy for veterinary medicine follows advances in human radiation oncology. It can be delivered using a wide range of techniques, including: 2-D conventional radiotherapy; 3-D conformal radiotherapy; 4-D radiotherapy (motion management); intensity modulated radiotherapy; stereotactic radiosurgery; stereotactic radiotherapy; stereotactic body radiotherapy; volumetric modulated arc therapy; robotic radiotherapy; and intraoperative radiotherapy.

Positioning of animals and verification of target localization can be performed with film screen or computed radiography detectors, and with treatment beam (MV) portal images using an electronic portal imaging device. Electronic portal imaging devices can also monitor dose on-line.

Other in-room image guided radiotherapy devices that use ionizing radiation are a low energy X ray source (kV) that can produce digital radiography, tomotherapy (MV computed tomography), megavoltage cone beam computed tomography and kilovoltage cone beam computed tomography.

Brachytherapy can be performed by placing radioactive sources or electronic brachytherapy devices directly into or in contact with the animal (by interstitial, intracavitary, surface or intraluminal techniques). A brachytherapy implant can be temporary or permanent. Afterloading devices allow for high dose rate sources to be placed into guides that have already been inserted into the body. In some instances, low dose rate sources may be introduced manually.

Note that pulsed dose rate brachytherapy equipment is increasingly used in a human brachytherapy setting; such techniques are of no use in a veterinary setting, however, because of the unfeasible safety constraints and logistics for animals.

5.2. SAFETY OF VETERINARY RADIATION THERAPY FACILITIES AND RADIOLOGICAL EQUIPMENT

5.2.1. Radiation therapy facilities

5.2.1.1. Location and site

A veterinary radiation therapy facility needs to be located on a site that makes it as simple as possible to comply with requirements for radiation protection. Operational efficiency and initial cost, as well as provision for future expansion, and provision for possible replacement
of the therapy unit with a unit that operates at higher energy and/or an increased workload, need to be considered in locating a new veterinary radiation therapy facility.

Radiation therapy rooms are often located on the periphery of a veterinary facility. This is to minimize difficulties arising with radiation protection due to radiotherapy rooms being adjacent to areas of high occupancy. The option of being able to construct rooms below ground level, with the potential for a reduced need for substantial shielding, may also influence the choice of site.

In addition to on-site considerations, the surrounding environment also needs to be considered; e.g. whether the site is adjacent to residential or industrial areas, whether there is general public access, and what are the uses of the surrounding area. These factors all relate to ensuring that public exposure outside — and above and below, if these areas are occupied — the radiation therapy facility is consistent with compliance with the requirements for public exposure.

For purposes of physical security, veterinary radiation therapy facilities in which sealed radioactive sources are used need to be located in areas where access by members of the public to rooms where sources are used and stored can be restricted.

5.2.1.2. **Design of rooms in the radiation therapy facility: general considerations**

A typical veterinary radiation therapy facility consists of these main areas: reception; consulting areas; area for external beam radiation therapy; brachytherapy area (including source storage area); imaging area; and treatment planning area. Provision for the incorporation of radiation safety features into these areas is best made at the stage of facility design.

As structural shielding for radiotherapy facilities is very heavy, care needs to be taken that the weight of the shielding can be supported by the building’s structure. This is especially important when machines are replaced by higher energy machines, such as when a cobalt-60 unit is replaced with a linear accelerator.

Access to the radiation therapy facility and its treatment rooms needs to be considered. This includes provision for the delivery of equipment.

The design of the facility needs to include an air conditioning system sufficient to maintain the temperature and humidity in the treatment room within the parameters defined by the manufacturers of the equipment. In addition, a ventilation system with four to six air changes per hour is advisable for removing any ozone generated by radiation [41].
The layout needs to take into account the workload and staff. Wherever possible, treatment rooms need to be surrounded with rooms that have low or controlled occupancy.

Further information on radiation protection in the design of radiotherapy facilities is provided in Ref. [42].

Physical signage giving information on where different areas are located and designating hazardous areas, preferably in both words and picture format, is beneficial. Colour coding of controlled areas and supervised areas is also helpful.

Radiation therapy facilities where radioactive sources are used may need technical measures to be taken so that unauthorized access to sources can be prevented. Such technical measures need to be independent of any interlocks that terminate the radiation beam during normal operation.

Fire fighting equipment needs to be available in all areas. In a brachytherapy unit, for example, this is important in order to be able to preserve the integrity of radioactive sources in the event of a fire [43].

5.2.1.3. Design of rooms in the radiotherapy facility: treatment rooms for external beam radiation therapy at high energy and for afterloading brachytherapy at high dose rate

External beam radiation therapy and high dose rate brachytherapy need to be carried out in the veterinary radiation therapy facility in treatment rooms designed for the purpose.

In a veterinary setting, the same shielded treatment room may be shared between high dose rate brachytherapy and external beam radiation therapy; however, there must be a physical barrier to prevent both modalities from being used at the same time.

The size of the treatment room will depend on many factors, including the type of treatment and the in-room imaging equipment, and the intended techniques of the treatments. The treatment room needs to be large enough to allow for the full extension of the couch in any direction. The room also needs to allow for rotation of the gantry and needs to provide adequate space for the safe use of the equipment for anaesthesia. There needs to be sufficient space to allow staff to walk around the room, and for safety procedures (e.g. to keep free access to emergency off switches).

Care needs to be taken when a new machine or unit is to be introduced into an existing treatment room. The size of the room and the specification for shielding need to be adequate for the new equipment and practices. This can be particularly relevant in the case of the
introduction of intensity modulated radiotherapy, or changing from cobalt-60 to the use of a linear particle accelerator, or the installation of a non-isocentric unit, for instance.

More information on the design of radiotherapy facilities can be found in Ref. [42].

The treatment room is not to be used for the recovery of animals from anaesthesia or the housing of animals. No other animals are to be left unattended in the room while an animal is being treated.

5.2.1.4. Design of rooms in the radiation therapy facility: manual and low dose rate brachytherapy

Rooms used for storage, preparation and implantation of sealed radioactive sources have to be designed for safety. Appendix IV provides guidelines on typical radiation safety features of such rooms. For facilities without a dedicated storage location, consideration has to be given to transferring sources back to the manufacturer upon completion of the procedure.

Animals with low dose rate implants inserted are to be kept in isolation in a shielded room. In some cases, such as in the treatment of large animals (e.g. horses), this may be a stable isolated from the rest of the facility and with a temporary controlled area designated around it.

In such a case, if it is feasible and safe, the implantation procedure could be carried out in the stable to avoid walking the treated animal from the treatment room to the holding rooms and/or the stable, and to reduce the risk of movement or loss of the radioactive implant. In the rooms and/or the stable, whenever possible, mobile shielding needs to be provided for radiation protection for veterinary technologists and visitors.

In facilities where low dose rate brachytherapy is routinely used, an area radiation monitor may be placed at the entrance to the treatment area to detect a source or an animal with a source leaving the room or the controlled area (see Fig. 30). In all situations, and for ensuring that after treatment no source remains in the animal, in the bedding or anywhere in the area, a portable monitor needs to be available for monitoring these items, in addition to the area radiation monitor.
Fig. 30. An area monitor placed at the entrance and/or exit to the treatment area to detect a source leaving the room. (Courtesy: ??)

5.2.1.5. Design of rooms in the radiation therapy facility: shielding considerations

Radiation therapy facilities typically need significant shielding, especially for the treatment rooms, to ensure that the requirements for radiation protection for occupational exposure and public exposure are met. Information on radiation protection in the design of radiotherapy facilities is provided in Ref. [42].

Second-hand equipment is often used in veterinarian radiotherapy. In many cases modifications are made to the equipment to take into account the constraints on shielding of the room. For example, a barrier needs to be incorporated to disable use of the highest photon energy in a dual MV energy machine to ensure that the equipment can only be used at the energy for which the room was designed.

A final assessment of the adequacy of shielding needs to be performed by the qualified expert in radiation protection and the radiation protection officer after construction and installation of the equipment has been completed, and prior to veterinary use. This may be achieved by means of a comprehensive radiation survey.
5.2.2. Radiological equipment, software and ancillary equipment

Licensees are required to take responsibility for the radiation safety of radiological equipment to be used in veterinary radiation therapy facilities. Licensees may impose purchasing specifications that include conditions set to meet relevant international standards of the and ISO, and/or equivalent national standards. Radiation sources, including radioactive material, equipment and accessories are to be purchased only from suppliers who meet national requirements for such dealings.

Displays, gauges and instructions on operating consoles of the radiological equipment, instruction and safety manuals that are to be used by operators, maintenance and service manuals, and instructions for maintenance and service engineers and technicians all need to comply with standards of the International Electrotechnical Commission and the International Organization for Standardization. They also all need to be made available, as far as possible, in the local language.

Procedures for the purchase, installation, acceptance, commissioning, use, maintenance and quality control of all equipment (hardware and software) need to be developed with the involvement of a qualified expert in radiation protection, together with other radiation therapy professionals as appropriate and the radiation protection officer.

For the radiological equipment in use, specific criteria for acceptability need to be defined in order to indicate when remedial action needs to be taken, including, if appropriate, taking equipment out of service.

5.2.2.1. Design features of veterinary radiological equipment: general considerations

For the benefit of animals being treated, the design of the radiological equipment and the design of procedures (for maintenance and service) need to be such that their performance is always reproducible, accurate and predictable. The radiological equipment used for radiation therapy in veterinary facilities is designed and manufactured for radiation therapy for people: it is medical radiological equipment (as defined in GSR Part 3 [2])\(^6\). There is no specific radiation therapy equipment designed for veterinary purposes.

\(^6\) Medical radiological equipment is radiological equipment used in medical radiation facilities to perform radiological procedures that either delivers an exposure of an individual or directly controls or influences the extent of such exposure. The term applies to radiation generators, such as X ray machines or medical linear accelerators; to devices containing sealed sources, such as \(^{60}\)Co teletherapy units; to devices used in medical imaging to capture images, such as gamma cameras, image intensifiers or flat panel detectors, and to hybrid systems such as positron emission tomography–computed tomography scanners.
Radioactive sources for teletherapy or brachytherapy need to meet relevant standards of the International Organization for Standardization [44, 45, 46].

Recording and verification (record and verify) systems and their related interfaces with imaging systems, treatment planning systems, treatment delivery systems, image storage systems and administrative data storage systems (e.g. picture archiving and communication systems and radiology information systems) are systematically verified for all their functionalities and for data integrity.

If parameters are incorrectly introduced into the system, systematic treatment errors will occur. The record and verify system is therefore subject to periodic quality assurance. Detailed guidance on record and verify systems is provided in Refs. [47, 48]. Further information can be found in Ref. [19].

5.2.2.2. **Design features of veterinary radiological equipment: external beam therapy**

Radiological equipment used for external beam therapy has to meet the specifications given in relevant International Electrotechnical Commission standards [49–57]. Guidance on design specifications and performance is provided in Refs [58–61], as appropriate. The following considerations are included:

1. Safety interlocks or other means designed to prevent the veterinary use of the machine in conditions other than those selected at the control panel are provided.
2. The design of equipment permits interruption of the treatment from the control panel; after the interruption, resumption of treatment is possible only from the control panel.
3. Mechanisms for control of the radiation beam are provided, including devices that indicate clearly and in a fail-safe manner whether the beam is ‘on’ or ‘off’.
4. The radiation field within the treatment area in the absence of any modifiers of the radiation beam (such as wedges or multileaf collimators) are as uniform as practicable and the non-uniformity is stated by the supplier. The non-uniformity of flattening filter free (FFF) beams is also specified by the supplier.
5. The design of the unit permits exposure rates outside the treatment area due to radiation leakage or scattering to be kept as low as reasonably achievable.
6. If primary shielding is incorporated into the equipment, electrical or mechanical interlocks are provided to avoid the beam being directed towards secondary barriers if the primary shielding does not intercept the beam.
In designing accelerators with energies higher than 10 MeV, it is advisable that manufacturers minimize potential hazards from radiation induced neutron activation of animals and materials in a treatment room (by induced radioactivity as a secondary effect of radiotherapy) [62].

5.2.2.3. Design features of veterinary radiological equipment: brachytherapy

Radiological equipment used for brachytherapy needs to meet the specifications given in Ref. [63] and needs to follow the guidance in Refs [58, 64], as appropriate.

Low dose rate and high dose rate sources have to be accompanied by a source certificate specifying: (a) the source strength in terms of reference air kerma rate in air or equivalent quantity as recommended by the International Commission on Radiation Units and Measurements [65], at a specified distance, for a specified date; (b) the quality control tests applied to the source, including leakage and contamination tests.

Applicators for brachytherapy are manufactured specifically for the source to be used or to be compatible with it. To avoid encapsulation and/or rupture of the applicator due to radiation damage, the sources are never left in applicators (pre-loaded applicators) in between veterinary procedures. When not in use, all brachytherapy sources need to be stored safely and securely.

Sources using beta emitters, such as $^{90}$Sr in ophthalmic applicators, are provided with shielding of low atomic number to minimize bremsstrahlung while they are in storage and in preparation for use.

5.2.2.4. Design features of treatment planning systems

The design features of the treatment planning system need to meet the veterinary goals of the radiation therapy facility. There are commercially available treatment planning systems that meet the requirement IEC 62083 [57] and that can be adapted to the application [66].

5.2.2.5. Design features of simulators and imaging equipment

The computed tomography scanners used as virtual simulators need to be designed so that animals can be simulated in the treatment position. This needs to include the positioning lasers, which need to be consistent with those of the treatment rooms. Guidance on radiological equipment used for imaging as part of radiation therapy, either pre-treatment, during treatment (in image guided radiotherapy) or for follow-up, is given in Section 3. Guidance applicable to
2-D imaging devices that are sometimes used in veterinary brachytherapy is given in Section 3.

5.2.2.6. Ancillary equipment

The radiation therapy facility needs to have equipment, instruments and test objects for reference and for relative dosimetry that are appropriate for the type of measurement needed for characterization of the beam and for quality control. This may include ionization chambers (thimble, plane-parallel and well type), solid state detectors, detectors for small-field dosimetry, electrometers, thermometers, barometers, phantoms, and geometry and mechanical test tools. Further guidance on appropriate equipment, instruments and test objects is given in Refs [58, 61, 63, 67–69].

Facilities with remote afterloading brachytherapy need to have equipment for source handling in the event of a failure of the afterloading unit, including: a storage container in the treatment room, to serve as an emergency source container in case of failure of the afterloader in retracting the source, a remote manipulator, wire cutters and a Geiger–Müller tube detector for location of sources.

The radiation therapy facility needs to be equipped with calibrated and maintained instruments for radiation monitoring (area detectors and portable and/or survey meters), including Geiger–Müller detectors and ionization chambers with electrometers or scintillators. For accelerators with energies of 10 MV and above, access to a neutron measuring instrument is advisable. Other necessary equipment is source handling equipment, including a magnifying glass, source manipulators (such as forceps, tweezers or tongs), clippers or wire-cutters, and several shielded containers.

5.2.2.7. Security of sources

The objective of security of sources is to ensure continuity in control and accountability for each source at all times. Guidance on security of sealed sources can be found in Ref. [16].

In a veterinary radiation therapy facility, sources can include sealed sources used in teletherapy and brachytherapy. Situations that are critical with regard to security of sources in a radiation therapy facility include receipt of sources, storage of sources and movement of sources within the facility.

The licensee of the radiation therapy facility needs to develop procedures to ensure the safe receipt and safe movement of radioactive sources within the facility. The licensee also
needs to establish controls to prevent theft, loss or unauthorized withdrawal of radioactive material or entrance of unauthorized personnel to controlled areas. An inventory of sources needs to be maintained, with procedures in place to check and confirm that sources are in their assigned locations and are secure.

5.2.2.8. **Maintenance of equipment**

Properly functioning equipment is essential to the efficacy of diagnostic and therapeutic procedures. Maintenance and servicing of radiological equipment needs to be included in the quality assurance programme. The maintenance and servicing is usually performed by appropriately authorized engineers or technicians who understand the specifications of veterinary radiological equipment.

The maintenance and servicing can be carried out by means of a maintenance contract (preventive and corrective) with the manufacturer, or by in-house staff or a third party contractor. Maintenance covers not just the veterinary radiological equipment and its hardware, but also software, networks, databases and other support systems in the radiation therapy facility (e.g. picture archiving and communication systems and radiology information systems).

Maintenance of the radiotherapy equipment and imaging equipment or equipment for planning treatment may affect the accuracy of the physical or veterinary dosimetry, or the safe operation of the equipment. In such cases, a radiation therapy physicist needs to perform specific tests or measurements to confirm that the equipment is operating satisfactorily before it is used for treating animals.

Maintenance and servicing of equipment is to be completed at intervals as recommended by the manufacturer or by the regulatory body. Equipment that is being serviced is not to be used for veterinary imaging until the service is completed.

The engineer or technician carrying out maintenance and servicing needs to follow rules for radiation protection, rules for general health and safety, and procedures established by the employer, as well as the relevant rules and procedures of the veterinary radiation facility.

Records of completed maintenance (preventative maintenance and corrective maintenance) and servicing need to include a written report for each piece of equipment describing findings and corrective actions. These reports are to be archived as part of the quality assurance programme.
5.3. OCCUPATIONAL RADIATION PROTECTION IN VETERINARY RADIATION THERAPY

5.3.1. General

For radiological procedures in radiation therapy, occupationally exposed workers are usually the veterinarians and the veterinary technologists and veterinary nurses. In addition, medical physicists support radiotherapy activities in some facilities by providing advice or by performing treatment planning and quality assurance, routine maintenance procedures and checks.

Occupationally exposed workers may also include service engineers and some contractors, depending on their duties.

Workers in veterinary radiation therapy facilities who are exposed to radiation from sources that are not required by or directly related to their work, such as other veterinary nurses, cleaners and other support staff involved in the management of animals, are required to be afforded the same level of protection against such exposure as members of the public (see para. 3.78 of GSR Part 3 [2]). Information needs to be provided to such workers on the relevant safety aspects and local rules.

This subsection provides guidance very specific to radiation therapy. More general and comprehensive recommendations and guidance on occupational radiation protection that are applicable to all areas of radiation use (including non-medical uses) are provided in Ref. [24]. This includes recommendations and guidance on radiation protection programmes, assessment of occupational exposure and providers of dosimetry services.

5.3.2. Arrangements under the radiation protection programme

5.3.2.1. Classification of areas

In a radiation therapy facility, all treatment rooms for external beam radiation therapy and remote afterloading brachytherapy, storage and handling areas for radioactive sources, and rooms where imaging procedures or simulation procedures are performed need to meet the criteria for controlled areas, and need to be so designated.

Supervised areas may include areas surrounding brachytherapy rooms or around storage and handling areas for radioactive sources.
The area around the control panel for all radiological equipment used in radiation therapy will be classified as a supervised area, even though radiation levels may be very low owing to the design of the shielding.

In order to avoid uncertainties about the extent of controlled areas and supervised areas, their boundaries will, when possible, be walls and doors, partitions or other physical barriers, clearly marked or identified with ‘radiation area’ signs.

5.3.2.2. Local rules and procedures: general

GSR Part 3 [2] establishes a hierarchy of preventive measures for protection and safety, with engineered controls, including structured shielding and ancillary shielding, specific physical barriers, signs and interlocks, supported by administrative controls and personal protective equipment.

To this end, and as required in GSR Part 3 [2], written local rules and procedures are established for a radiation therapy facility. The purpose of the written rules and procedures is to ensure protection and safety for operators and other individuals.

The local rules and procedures include measures to minimize occupational exposure in both normal work and unusual events. The local rules and procedures also cover the wearing, handling and storage of personal dosimeters, and specify investigation levels and follow-up actions.

All individuals involved in using radiation in radiation therapy need to know and follow the local rules and procedures. The development and review of these local rules and procedures may involve the radiation protection officer and a qualified expert in radiation protection.

Equipment (hardware and software) needs to be operated in a manner that ensures satisfactory performance at all times with regard to both the tasks to be accomplished and radiation safety. The manufacturer’s operating manual is an important resource in this respect, but additional procedures are also considered. The final documented set of operational procedures is approved by the licensee of the radiation therapy facility and incorporated into the facility’s quality management system.

Radiotherapy staff need to understand the documented procedures for operation of the equipment with which they are working, including the safety features. They also need to be trained, with periodic refresher training, in what to do when things go wrong. Additional
education and training may be necessary when new devices or techniques are introduced into radiation therapy practice.

Many local rules and procedures address aspects of some or all of radiation protection against occupational exposure, animal safety and radiation protection against public exposure, either directly or indirectly, as well as ensuring a successful application of the treatment.

For external beam radiotherapy and high dose rate brachytherapy, no one can be in the treatment room during the delivery of treatment to the animal. All attending operators need to be in appropriately shielded areas.

Safety features such as interlocks, the presence of accessories, such as the T-bar for manual retraction of cobalt-60 sources, and the functionality of survey meters need to be checked daily prior to treatment of animals.

Sealed sources need to be subject to leak tests prior to their first use and at regular intervals thereafter, as required by the regulatory body [454].

Area surveys need to be performed periodically (e.g. every six months) or as required by the regulatory body around all treatment units and check sources, including cobalt-60 units, shielded safes, and storage facilities for low dose rate sources and high dose rate sources.

5.3.2.3. Local rules and procedures: external beam radiation therapy

Safe operation of external beam radiation therapy units needs procedures for area surveys, interlock checks and leak tests (for sealed sources), and procedures for contingencies such as a source becoming stuck in the ‘on’ or ‘partially on’ position. Such procedures need the necessary equipment to be available, calibrated and in working order, including:

(a) A radiation monitor;
(b) Capabilities for leak testing (for radioactive sources);
(c) Personal alarm dosimeters, especially for unplanned exposures.

The procedures for the use of radiation monitoring equipment need to take account of the fact that some instruments may ‘lock up’ in a high radiation field and give erroneous readings. The procedures also reflect the fact that this phenomenon, if it occurs, can be identified by starting monitoring from outside the room in which the source is located, i.e. monitoring from the areas of lower dose rates to the areas of higher dose rates.

The presence of other individuals in the area of the control panel is kept to the minimum necessary so as to avoid distractions to the operator.
Irradiations that involve long uses of high energy X rays, such as beam calibration, dosimetry and quality control measurements, are scheduled to take place at the end of the treatment day or at weekends, so that neutron activated radionuclides (especially the longer lived ones) can decay significantly overnight.

Animals receiving external beam treatments, including small animals (e.g. dogs and cats) and large animals (e.g. horses), may be anaesthetized and strictly immobilized when being treated and/or irradiated in the treatment room. This helps to avoid movement or falling, and allows accurate dosimetry, as well as reducing the risk of the equipment being damaged during irradiation (see Figs 31–33).

Fig. 31. Dog under general anaesthesia in external beam radiation therapy (linear particle accelerator teletherapy). Note the positioning cushion and ties. (Courtesy: ??.)
5.3.2.4. **Local rules and procedures: brachytherapy: general considerations**

Source inventories need to be maintained, giving the radionuclide, the location and the activity, with a reference date, for each source at the facility, as well as its serial or batch number, and a unique identifier. Sources are never to be left on preparation surfaces: they need to be either in storage or in transit or in use.

Regular leak tests may be performed for sealed sources as required by the regulatory body. Area surveys are to be performed periodically around source storage facilities for low
dose rate sources, high dose rate sources and sources to be used in permanent implants.

Facilities for the storage of sources are to be marked to warn that they contain radioactive materials. Emergency contact information is to be posted conspicuously as required by the regulatory body. Storage rooms for sources need to be kept locked at all times.

After temporary brachytherapy treatment, all brachytherapy sources will be removed from the animal, accounted for and replace in storage. The animal under treatment needs to be monitored with a radiation survey meter to ensure that all radioactive sources have been removed. Mobile containers and portable equipment containing radioactive sources need to be removed to storage or to a secure place when not in use.

Sterilization processes in brachytherapy need to be appropriate and consistent with manufacturers’ recommendations to prevent damage to sources and applicators that could have consequences for safety.

Among other safety checks, the catheters, couplings and transfer tubes need to be checked before and after each treatment, to ensure that there are no obstacles that would prevent movement of the source. Further details on safety checks are given in Ref [70].

5.3.2.5. **Local rules and procedures: brachytherapy: additional for low dose rate sources**

In the case of temporary low dose rate brachytherapy applications, both manual as well as remotely controlled, the following information is to be displayed at the entrance to the treatment room: identification of the animal; sources; date and time of insertion and removal; nursing required; time and/or distance allowance for veterinary technologists and visitors; use of mobile shielding, where available; and concise instructions for unplanned removal of the source and applicator, and for dealing with an emergency, including contact details.

An animal with a removable source may only leave the afterloading or treatment room in exceptional circumstances and needs to be accompanied by an attendant from the radiation therapy facility at all times.

Reusable sources need to be inspected visually for possible damage after each use, by means of magnifying viewers and a leaded viewing window in a shielded work area.

There needs to be a diagram at the safe for storage of sources that shows the exact location of each source within the safe, thus reducing the time taken to locate and identify a source.

Sources are only to be handled with long forceps or tongs and never directly by hand. When transporting sources, a mobile shielded container needs to be used and the shortest route
possible needs to be taken. A container with a long handle and/or a long handled trolley is used (see Fig. 34).

![Image of a mobile shielded container](image)

**Fig. 34.** When transporting sources, a mobile shielded container needs to be used and the shortest route possible needs to be taken. A container with a long handle and/or a long handled trolley is used. (Courtesy: ??)

Reusable sources that come into direct contact with body tissues will need cleaning and sterilization after each use. This can subject the sources to possible damage from heat, abrasion, chemical reactions and mechanical stresses. These sources therefore need to be inspected before and after each use.

Work surfaces need to be continuous, easy to clean and brightly lit to make it easy to find any source that has been dropped.

If the room for the storage and preparation of sources is also the applicator loading room, there may be a sink for cleaning the applicators. However, a sink can also lead to a loss of sources to the sewerage system when a source is left in the applicator and put in the sink. Such losses are preventable by placing a filter in the sink’s drain.

For brachytherapy treatments at low dose rate, animals may only be anaesthetized or heavily sedated for the implantation of the treatment guides and radioactive material. Continuous sedation during the period of treatment may only be necessary if the behaviour of
the animal is a concern, and if there is a risk that its behaviour could affect treatment by removing or damaging the implant.

Regular surveillance of the animal treated with radiopharmaceuticals that are still incorporated is necessary by the mean of direct visual examinations and camera monitoring. In some cases, the difficult behaviour of an animal could be considered as a contraindication for low dose rate brachytherapy treatment and the veterinary practitioner may consider alternative treatment options for the animal.

5.3.2.6. **Local rules and procedures: brachytherapy: additional for high dose rate sources**

For brachytherapy treatments at high dose rates, animals may only be anaesthetized or heavily sedated for the implantation of the treatment guides and radioactive material, as well as during each treatment session in the appropriate shielded treatment room. General anaesthesia is recommended for small companion animals, whereas sedation can be appropriate for larger animals (e.g. horses), provided that a monitoring camera is used during treatment (see Fig. 36).

![Fig. 36. Horse undergoing high dose rate brachytherapy. Note that the horse is sedated. (Courtesy: ??)](image)

In such cases, where only sedation is being used, attention needs to be paid to minimizing movements of connecting cables and minimizing tension between the animal and the afterloader. The afterloader itself needs to be protected by using a physical barrier between the animal and the treatment unit.
It may be useful to interrupt the treatment at the time the source is being retracted between two implants to allow a direct veterinary evaluation of the status of sedation of the animal. The state of anaesthesia or the status of sedation of the animal during treatment may be questionable. In such a case, it is necessary to interrupt treatment immediately to allow retraction of the source and direct evaluation of the anaesthesia and/or sedation of the animal. Once the state of anaesthesia or the status of sedation has been evaluated and adapted as necessary, the brachytherapy treatment can be resumed.

In some cases, the difficult behaviour of an animal could be considered a contraindication for high dose rate brachytherapy treatment, and the veterinary practitioner may consider alternative treatment options for the animal.

The high dose rate afterloader needs to undergo routine quality assurance tests at the beginning of each treatment day [70].

Safety precautions for an emergency need to include the availability of an emergency container in the treatment room. There also needs to be an emergency kit containing surgical clamps and long handled forceps for manipulation of the source guide tubes and applicators if the source fails to return to the safe, or for other source retrieval actions. The emergency container needs to be placed close to the animal. It needs to be sufficiently large that it can accept the entire applicator assembly containing the source removed from any animal.

Manufacturers need to provide suggested emergency procedures if the source fails to return to the safe position. These procedures generally consist of a short single page synopsis, suitable for posting in an appropriate place, of the necessary sequential steps involved in the emergency procedure. The procedures are based on the assumption that the physical integrity of the applicator is maintained. These procedures are specific to the actual afterloading unit. In general, though, each step is based on the assumption that if the action taken fails to lead to recovery, then the subsequent actions are necessary. The general sequence is:

1. Observation at the console of an error message and emergency indicators (audible and visible alarms);
2. Recovery at the console (e.g. pressing an emergency off, emergency stop or emergency source retract button);
3. Entry into the room with a portable radiation survey meter (opening the door activates the interlock that retracts the source);
4. Observation of radiation levels in the room (by mounted monitors or portable survey devices).
(5) Recovery at the afterloading unit (pressing an emergency off, emergency stop or emergency source retract button on the remote afterloading unit);

(6) Manual retraction of the source (using a hand crank);

(7) Survey of the animal and the survey of the afterloader (to confirm that the source is in the safe);

(8) Removal of the applicator and placement in the emergency container;

(9) Survey of the animal and survey of the emergency container (to confirm that the source is not in the animal and that it is in the emergency container);

(10) Removal of the animal from the vault with subsequent redundant survey monitoring.

(11) Informing of the personnel responsible for the maintenance of the afterloader, the radiation protection officer and, depending on national rules, the regulatory body.

5.3.2.7. Local rules and procedures: manual brachytherapy

For implants with sources of different activities, after verification of the source strength, the source or the source holder may be marked with unique identifiers (for example, a pre-established colour that cannot be compromised by body fluids), for visual recognition and to prevent the possibility of confusion between different sources or batches. Containers utilized for transport of radioactive sources are subject to the requirements established in the IAEA’s Regulations for the Safe Transport of Radioactive Material [15].

All movements of sources are to be recorded, with the appropriate signature of the person responsible for the move. The licensee needs to designate a person to be accountable for the sources. This person needs to keep records of source orders, of the removal of sources for therapeutic use from the safe, and of their return to the safe, with signatures.

Reusable sources need to be inspected visually for possible damage after each use by means of magnifying viewers and a leaded viewing window in a shielded work area. Sources are only to be handled with long forceps or tongs and never directly by hand.

A mobile shielded container needs to be available for transport of sources and the shortest route possible needs to be taken. A container with a long handle and/or a long handled trolley is used (see Fig. 35).

Reusable sources that come into direct contact with body tissues will need cleaning and sterilization after each use. This can subject the sources to possible damage from heat, abrasion,
chemical reactions and mechanical stresses. These sources therefore need to be inspected before and after each use.

5.3.2.8. *Precautions to be observed during the cutting and handling of $^{192}$Ir wires*

(1) There is good illumination of the work surface.

(2) Appropriate tools and equipment such as forceps, cutting devices and magnifying glasses are available and are used.

(3) If $^{192}$Ir wires are cut off for immediate use, a container to hold cut lengths is provided and labelled.

(4) Radioactive waste is collected and stored in adequate containers, and properly transferred to another appropriate licensee or an authorized waste disposal facility.

(5) Surfaces and tools are properly decontaminated.

5.3.2.9. *Local rules: imaging and simulation*

Local rules and procedures for performing imaging procedures as part of preplanning and simulation need to follow the guidance, where appropriate, given in Sections 3 and 4r. Additional information relevant to local rules specific to using imaging equipment as part of image guided radiotherapy is given in Ref. [71].

5.3.2.10. *Personal protective equipment and in-room protective devices*

GSR Part 3 [2] requires that personal protective equipment and in-room protective equipment be available and be used when structural shielding and administrative controls alone cannot provide the necessary level of occupational radiation protection. The need for this protective equipment has to be established by the radiation therapy facility’s radiation protection officer or by a qualified expert in radiation protection.

For current external beam treatment procedures in radiation therapy, personal protective equipment is not usually necessary. However, during animal preparation, source implantation or manual afterloading techniques in brachytherapy, and in the simulation and/or preplanning phase when imaging equipment is in use (e.g. radiography, C-arm computed tomography), the relevant requirements given in GSR Part 3 [2] and covered in this Safety Report in Section 3 apply.

In the case of manual handling of sources for brachytherapy, protective equipment such as shielding blocks on the workbench and a lead glass screen need to be used, as well as appropriate devices for handling sources.
For nursing of animals treated with either temporary low dose rate brachytherapy or permanent implants, consideration may be given to the use of movable shielding in the room [71].

Protective equipment for emergencies in brachytherapy, e.g. a source lodged in at high dose rate, needs to include an emergency container suitable for applicators and/or sources.

5.3.2.11. Monitoring of the workplace

GSR Part 3 [2] sets out the requirements and responsibilities for monitoring of the workplace. Workplace monitoring comprises making measurements in the working environment and interpretation of the results. Workplace monitoring serves several purposes, including routine monitoring; special monitoring for specific occasions, activities or tasks; and confirmatory monitoring to check assumptions made about exposure conditions.

Workplace monitoring can be used to verify the doses from occupational exposure of personnel whose work involves predictable low levels of radiation. It is particularly important for staff members who are not individually monitored. Further general recommendations and guidance on workplace monitoring are given in Ref. [24].

Workplace monitoring in areas around each item of radiological equipment (for therapy and imaging) in the radiotherapy facility, when it is being operated, needs to be carried out when:

1. Construction of the room and the shielding have been completed, either new or by renovation, and before the room is first used for veterinary purposes;
2. New or substantially refurbished equipment is commissioned;
3. Source replacements have taken place in teletherapy or in remote controlled brachytherapy;
4. New software for veterinary radiological equipment is installed or there is a significant upgrade;
5. New techniques are introduced;
6. Servicing has been performed on radiological equipment, which may have an impact on the radiation delivered.

Initial workplace monitoring includes measurements of radiation leakage from the equipment and of the radiation levels of the accessible areas around, above and below
irradiation rooms using suitable phantoms. This initial monitoring needs to be performed as part of acceptance tests, prior to veterinary use of equipment.

In addition, exposure levels in teletherapy rooms with radioactive sources and in treatment rooms for high dose rate brachytherapy may be continuously monitored by the use of permanently installed area monitors. The area for source storage and handling needs to be monitored with a survey meter immediately following the removal from, or the return to, storage of brachytherapy sources.

For treatment rooms where there is a possibility of induced activity, e.g. rooms with high energy X ray beams (>10 MV), consideration needs to be given to the use of appropriate area monitors to detect the presence of neutrons and other radiation being emitted from induced radionuclides in the treatment room [62, 72].

Workplace monitoring needs to be done in association with brachytherapy procedures. Soon after implantation of the sources, a survey of exposure rates in the vicinity of the animal is necessary.

All survey meters used for workplace monitoring need to be calibrated in terms of ambient dose equivalent. For radiation therapy procedures, the quantity is H*(10) in sieverts, with multiplier scales. The calibration needs to be current and traceable to a standards dosimetry laboratory. The meters need to be subject to regular tests for quality control.

5.3.3. Assessment of occupational exposure and workers’ health surveillance

5.3.3.1. Assessment of occupational exposure

As stated in GSR Part 3 [2], paras 3.99 to 3.102, individual monitoring is required for any worker who normally works in a controlled area and is likely to receive significant occupational exposure. Workers who may require individual monitoring include veterinary practitioners, veterinary radiation oncologists, medical physicists, the radiation protection officer, maintenance and servicing personnel, and any technical staff or other staff who spend time with animals with implanted radioactive sources.

Personal dosimeters are assigned to individuals for use during procedures in a particular facility. Personal dosimeters are not to be shared with other staff and are not to be worn in other facilities. For example, if an employee is issued with a dosimeter at a particular veterinary facility, it is to be worn at that veterinary facility only and not at any other veterinary facilities where he or she may also work.
Monitoring results can then be interpreted for the person working in a specific radiation therapy facility. This will allow for appropriate review of the effectiveness of the optimization of protection and safety for that individual in that facility. However, national regulatory requirements may differ from this advice, and these would need to be followed in those jurisdictions where they apply.

The monitoring period (i.e. period of use of a dosimeter) specified by regulatory bodies in most States is typically in the range of one to three months. A one month monitoring period is usually used for persons performing procedures associated with higher levels of occupational exposure. A longer monitoring period (two or three months) is more typical for personnel exposed at lower doses. A one month monitoring period would usually mean that the actual dose from occupational exposure is lower than the minimum detection level of the dosimeter, resulting in there being no detectable doses.

With a longer monitoring period, it is more likely that a reading can be obtained. Unnecessary delays in the return of, reading of and reporting of the doses recorded on dosimeters are to be avoided. Dosimeters need to be sent from the veterinary radiation therapy facility to the dosimetry service provider, which would then process the dosimeters and return the dose reports, all in a timely manner. Some regulatory bodies may specify a performance criterion for timely reporting.

There are three dose limits applicable to workers in radiation therapy: the limit for effective dose, and the limits for equivalent dose to the lens of the eye and equivalent dose to skin and extremities. The dosimeter being worn can be used to estimate one or more of the quantities used for the dose limits.

Depending on the work being performed by the person being individually monitored, there may be a preferred position for wearing the dosimeter, and more than one dosimeter may be used. In radiation therapy, dosimeters are usually worn on the front of the upper torso, as occupational exposure arising from most radiation therapy procedures results in the whole body being rather uniformly exposed. If specialized dosimeters, such as ring dosimeters for monitoring finger doses, are necessary, the manufacturer’s specific wearing instructions need to be followed.

When not in use, personal dosimeters are to be kept in a dedicated place and are to be protected from damage and from irradiation. If an individual loses his or her dosimeter, the individual needs to inform the radiation protection officer. The radiation protection officer
needs to perform a dose assessment, to record this evaluation of the dose and to add it to the individual’s dose record.

Where there is a national dose registry, information on the dose estimate needs to be provided in a timely manner. The most reliable method for estimating an individual’s dose is to use his or her recent dose history. In cases where the individual performs non-routine types of work, it may be better to use as the basis for the dose estimate the doses of co-workers having similar exposure conditions.

Additional direct reading operational dosimeters, such as electronic dosimeters, may be considered for use in a radiation therapy facility, e.g. in a new department or with the introduction of new modalities or procedures. Such devices can give the worker an instant indication of both the cumulative dose and the current dose rate, and may also allow the setting of an alarm for when a given level has been reached [24]. Such devices will also be helpful in emergencies. Extremity monitoring may be considered when radioactive sources with low dose rates are being manipulated.

5.3.3.2. Investigation levels for workers

Investigation levels are different from dose constraints and dose limits; they are used to provide a warning of the need to review procedures and performance, to investigate what is not working as expected and to take timely corrective action. Corrective actions need to be carried out when the dose received by a worker exceeds an investigation level.

In radiation therapy, for example, pro rata monthly values higher than 0.5 mSv (for the dosimeter worn on the torso) need to be investigated. Values higher than 15 mSv per month for hand or finger dosimeters also need to be investigated.

Abnormal conditions and/or events also need to trigger an investigation. In all cases the investigation needs to be carried out for the optimization of protection and safety for occupational exposure.

Investigation levels are also to be set for workplace monitoring, with account taken of exposure scenarios and the predetermined values adopted for investigation levels for workers. Further details on investigation levels are provided in Ref. [24].

An investigation needs to be initiated as soon as possible following a trigger or an event. A written report needs to be prepared concerning the cause, the determination or the verification of the doses received by workers, any corrective actions taken, and any instructions
or recommendations to avoid a recurrence. Such reports are to be reviewed by the licensee. In some cases, the regulatory body may also need to be informed.

5.3.3.3. Records of occupational exposure

Records of occupational exposure for each worker are to be maintained during and after the worker’s working life, at least until the worker attains or would have attained the age of 75 years and for not less than 30 years after cessation of the work in which the worker was subject to occupational exposure.

Apart from demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary radiation therapy facility for other purposes. These include assessing the effectiveness of the optimization of protection and safety at the facility, and evaluating trends in exposure.

National or local regulatory bodies might specify additional requirements for records of occupational exposure and for access to the information contained in the records. Employers are required to provide workers with access to records of their own occupational exposure (GSR Part 3 [2], para. 3.106(a)). Further general guidance on records of occupational exposure is given in Ref. [24].

5.3.3.4. Workers’ health surveillance

The primary purpose of health surveillance of workers is to assess the initial and continuing fitness of employees for their intended tasks. Relevant requirements are established in GSR Part 3 [2], paras 3.108 and 3.109.

No specific health surveillance relating to radiation exposure is necessary for staff involved in veterinary radiation therapy.

Special investigations involving biological dosimetry and further extended diagnosis and medical treatment would be necessary only if workers are exposed at doses much higher than the dose limits (e.g. doses of a few hundred millisieverts or higher) [24].

Under normal working conditions, the doses incurred due to occupational exposure in radiation therapy are low. No specific radiation related examinations are necessary for persons who are occupationally exposed to ionizing radiation, as there are no diagnostic tests that yield information relevant to exposure under normal working conditions.

It is, therefore, rare for considerations of occupational exposure arising from the working environment of a radiation therapy facility to influence significantly the decision about the
fitness of a worker to undertake work with radiation, or to influence the general conditions of service [24].

Counselling needs to be made available to workers who have had exposures in excess of dose limits, or who may have had such exposures, and information, advice and, if indicated, counselling is to be made available to any workers who are concerned about their radiation exposure.

In veterinary radiation therapy, workers who are concerned about their radiation exposure may include female workers who are pregnant or who may be pregnant. Counselling is to be given by appropriately experienced and qualified practitioners. Further guidance is given in Refs [24, 73].

5.3.4. Conditions of service and special arrangements

As required in GSR Part 3 [2], para. 3.111, special compensatory arrangements, or preferential consideration with respect to salary, special insurance coverage, working hours, length of vacation, additional holidays or retirement benefits, are neither to be granted nor to be used as substitutes for measures for protection and safety in accordance with the requirements of GSR Part 3.

5.3.4.1. Female workers who are pregnant

It cannot be made a requirement on a female worker in GSR Part 3 [2] to notify an employer of a suspected pregnancy or of breast-feeding. However, it is necessary that female workers understand the importance of making such notifications so that their working conditions may be modified accordingly (para. 3.113).

GSR Part 3 [2] establishes requirements for employers, in cooperation with registrants and licensees, to provide female workers who are liable to enter controlled areas or supervised areas or who may undertake emergency duties with appropriate information in this regard (GSR Part 3 [2], para. 3.113(b)).

The employer of a female worker, who has been notified by the female worker of her suspected pregnancy or that she is breast-feeding, is required to adapt her working conditions in respect of occupational exposure so as to ensure that the embryo or fetus or the breastfed infant is afforded the same broad level of protection as is required for members of the public (GSR Part 3 [2], para. 3.114).
The limitation of the dose to the embryo or fetus does not mean that a female worker who is pregnant is required to avoid work with radiation. The employer is, though, required to carefully review the working conditions with regard to exposure and potential exposure for female workers who have notified their employer of their suspected pregnancy.

For example, the dose to the fetus for a female worker who is pregnant and who is involved in source handling in manual brachytherapy, under normal conditions, may reach the dose limit for a member of the public (see Table 1). To prevent this from happening, rigorous restrictions on time, shielding and distance need to be put in place.

A possible adaptation is the reassignment of a female worker who is pregnant to duties where the likelihood of an accident or incident is unlikely or to a location that may have a lower ambient dose equivalent. Such reassignments need to be accompanied by adequate training. A further consideration is to avoid including female workers who are pregnant in the response to an incident or emergency, such as those described in Section 5.5.3; for example, with a cobalt-60 unit or a high dose rate brachytherapy unit.

When the dose limit of 1 mSv is applied for the embryo or fetus, the reading of a dosimeter may overestimate the dose to the embryo or fetus by a factor depending on the energy and type of the incident radiation (by a factor 10 for low energy X rays and about 2 for cobalt-60 and MeV X rays). The dose to the fetus may be monitored by using an additional dosimeter appropriately positioned [22, 24]. Information, advice and, if indicated, counselling needs to be made available for female workers who are or who may be pregnant.

5.3.4.2. Persons under 18 years of age

In many States there is the possibility of students of age 16 years or more, but under the age of 18 years, who are undertaking studies and training being subject to exposure. GSR Part 3 [2], para. 3.116, establishes requirements on access to controlled areas for persons under the age of 18 years, and the dose limits for such persons are more restrictive; see Table 1.

5.3.5. Protection of workers responding to incidents in a radiation therapy facility

The practice of radiation therapy is a planned operation, and when circumstances result in incidents that lead to, or that could lead to, unintended or accidental exposures of staff or of animals, they are still within the framework of a planned operation. The potential occurrence of exposure may be considered in advance and mitigatory actions developed accordingly.
Occupational exposure of staff responding to incidents is subject to the dose limits for occupational exposure. Mitigatory actions for incidents include considerations for the optimization of protection and safety for the workers responding.

The mitigatory actions also include allocation of responsibilities and provide for the education and training of the relevant staff in executing the mitigatory actions, which need to be periodically exercised. Most of these situations, for example the retraction of a high dose rate source, can be executed in a planned manner so that occupational exposures and doses received can be kept low.

### 5.3.6. Education, information, instruction and training

General guidance regarding education and training of veterinary professionals is presented in Section 2.5. The following guidance is additional guidance that is applicable to veterinary professionals working in diagnostic radiology and interventional radiology.

The objectives of the training include imparting knowledge of risks associated with radiation and mechanisms of risk reduction as well as training for operating specific equipment used for diagnostic imaging and interventional radiology in the veterinary facility, and for performing specific procedures.

Equipment specific training is usually provided by the applications specialist of the manufacturer, externally or in-house by a suitably qualified trainer and augmented by use of the equipment manual. Descriptions of best practice procedures can also be found in the scientific literature.

An example of the education and training in radiation protection for veterinary professionals are those developed by the Heads of European Radiological Protection Competent Authorities (HERCA) [17]. The HERCA guidelines are included as an Annex.

The HERCA guidelines include Table A-1 Core Learning Outcomes in Radiation Protection for Veterinary Doctors and Table A-3 Additional Learning Outcomes for Veterinary Doctors working in the Field of Radiotherapy that contain the knowledge, skills and competencies for veterinary practitioners.

The HERCA guidelines also include Table A-5 Core Learning Outcomes in Radiation Protection for Veterinary Radiographers and Veterinary Assistants and Table A-7 Additional Learning Outcomes for Veterinary Radiographers and Veterinary Assistants working in the
Field of Radiotherapy that contain that contain the knowledge, skills and competencies for veterinary technologists.

HERCA notes that the education and training requirements need to be met before veterinary professionals start work with radiation. HERCA also note that veterinary radiographers and veterinary assistance do not have to meet all the requirements set out in the document, depending on the scope of practice and the degree of autonomy that they are permitted in their country.

The veterinary practitioners in the veterinary facility need to be given the responsibility to provide information, instruction and training to other staff in the veterinary facility. These staff include veterinary nurses and animal handlers who may be required to assist in the performance of radiotherapy procedures.

5.4. RADIATION PROTECTION OF THE PUBLIC

5.4.1. General

Public exposure may arise from the performance of radiation therapy for persons in and around the radiation therapy facility.


5.4.2. Animal owners and other visitors

Visitors, including persons delivering goods or supplies, sales personnel, accompanying persons and escorts, and owners of animals in the facility, are required to be afforded the same level of protection against exposure as members of the public.

In radiation therapy, the role of animal owners is generally limited to accompanying animals to the veterinary facility. Access to the treatment areas for external beam radiation therapy or high dose rate brachytherapy is not permitted for any member of the public.

Brachytherapy treatments that involve permanent implants of sealed sources may lead to the exposure of persons who provide care to the animal. The radiation dose that animal owners and other individuals can receive during the treatment period of their animals is required not to exceed the dose limit for the public.
The radiation therapy facility may have written protocols for measures for the optimization of protection and safety for owners of animals undergoing low dose rate brachytherapy or animals with permanent implants. The measures may utilize the basic methods for radiation protection, i.e. time, distance and shielding. The written protocol may include the following:

1. Methods for ensuring that the animal owner receives a dose that is as low as reasonably achievable;

2. The values of the dose constraints to be applied, to ensure that the dose limit for members of the public is not exceeded (see Section 2).

5.4.2.1. Protection against external exposure and contamination

The primary means for protecting members of the public (such as visitors) against exposure is the shielding in place at the radiation therapy facility. The shielding needs to be sufficient that any public exposure resulting from being in an immediately adjacent area that is accessible by visitors, including outdoors and rooms above and below the radiation therapy room, that is accessible by visitors, would be in compliance with the dose limits for public exposure. The public exposure would preferably also be less than any dose constraint that the regulatory body may have established.

Animals receiving brachytherapy implants may cause exposure of members of the public in the radiation therapy facility and upon discharge. The radiation protection officer needs to establish rules to ensure that the dose from exposure of any member of the public will be less than the dose limit for public exposure and, preferably, lower than any applicable dose constraint.

Assumptions made for these calculations with regard to time and distance need to be consistent with the written instructions given to the owners of the animals at the time of release of the animal from the radiation therapy facility. Results of the calculations are to be recorded. Examples of such calculations are given in Ref. [74].

As required in GSR Part 3 [2], a radiation therapy facility needs to have arrangements in place to manage the release of animals that have permanent brachytherapy implants. Once the animal is released, two groups of persons need to be afforded appropriate radiation protection and safety: the general public who may encounter the animal, and persons in the animal owner’s close surroundings.
Furthermore, public exposure arising from a single source, such as an animal with implants, needs to be subject to dose constraints set at some fraction of the dose limits.

Prior to an animal’s release from a radiation therapy facility post-treatment, the facility’s qualified expert or radiation protection officer needs to confirm that the dose received does not exceed public dose limits. An acceptable method for estimating the acceptable activity of permanent implants for animals being released is to calculate the time integral of the ambient dose equivalent rate, with account taken of the activity, energy and half-life of the radionuclides.

The animal’s owner needs to be provided with written instructions on how to keep exposures of members of the public as low as reasonably achievable. Of particular concern are children and pregnant women in the animal’s surroundings.

The owner of an animal with permanent brachytherapy implants needs to be informed that if the animal is to undergo subsequent procedures, then the veterinarian needs to be informed of the presence of the implants.

In deciding on the appropriate activity at release of a particular animal, the licensee and the radiation protection officer need to take into account the transport and the living conditions of the animal. This includes, for example, the extent to which the animal can be isolated from members of the owner’s family, and the need to manage safely the animal’s excreta and body fluids, which may contain a migrating source. In some cases, such as if an owner has a family with young children, it will be necessary to discuss precautions to be taken to protect family members.

Animals that have received temporary low dose rate brachytherapy implants may also cause exposure of members of the public in the radiation therapy facility. In the facility, the radiation protection officer needs to establish rules to ensure that the dose from exposure of any member of the public will be less than the dose limit for public exposure and, preferably, lower than any applicable dose constraint. No animal will be released with a radioactive implant in place.

Precautions for purposes of radiation protection and safety may be necessary after the death of an animal with permanent implants, for an autopsy, or for a burial or cremation. These precautions need to be determined by the radiation protection officer. They will be determined on the basis of a generic safety assessment of the need for monitoring the personnel who carry
out these procedures, the need for monitoring the premises and the need for minimizing external radiation exposure and the potential for contamination.

Whole body monitoring and finger monitoring may be necessary for personnel engaged in an autopsy, since contamination and radioactive waste are likely to be generated [75]. A particular example is the cremation or incineration of an animal with permanent implants. In such cases, strict considerations of radiation protection would indicate the need to delay releasing the animal to the owner or to the cremation or incineration company until adequate decay has occurred. The cremation or incineration may not be permitted to be carried out, depending on the time of death and the half-life of the radionuclides concerned [74, 76].

5.4.2.2. Control of access

Access to areas where radiation is being used needs to be controlled to ensure that doses to visitors are below the dose limits for the public and below any relevant dose constraints.

Visitors are not allowed to enter treatment rooms or other controlled areas while they are in use. Exceptionally, a visitor, for example a veterinarian from another facility, may be permitted to enter a controlled area or a supervised area, accompanied at all times by a staff member who is familiar with the measures for protection and safety for the controlled area.

The radiation therapy facility needs to have written procedures specifying where and when such exceptions can be made and who may accompany the visitor. Particular consideration, in all cases, is to be given with regard to women who are or who may be pregnant, and children and other persons under the age of 18.

Controlled and supervised areas need to be clearly identified to help prevent inadvertent entry to areas where radiotherapy treatment or other radiological procedures are being performed. Further control can be afforded by the use of keys or passwords to restrict access to the control panels of veterinary radiological equipment to operators and authorized persons only.

5.4.3. Assessment of public exposure

A programme for monitoring public exposure arising from veterinary radiation therapy needs to include a dose assessment in the areas in and around the facility that are accessible to the public. This dose assessment can be carried out on the basis of the shielding calculations in the planning stage. These shielding calculations can be combined with results from area monitoring at the time of the initial operation of the facility and periodically thereafter. Records
of dose assessments need to be kept for a period that meets any relevant regulatory requirements, and in any case for at least 7–10 years.

5.4.4. Disposal of radioactive material

5.4.4.1. Radioactive sources no longer in use

When radioactive sources in the veterinary radiation therapy facility become surplus to requirements or are no longer viable for their veterinary purpose, the licensee is required to ensure that the sources are either transferred or disposed of appropriately. The licensee retains responsibility for the sources until the time of their transfer to another appropriate licensee or to an authorized disposal facility for radioactive waste. Guidance on the management of radioactive waste, applicable to radiation therapy facilities, is given in Ref. [27].

Specifically, for teletherapy equipment with a radioactive source, the licensee needs to do the following:

(a) The licensee needs to notify the regulatory body of any intention to transfer or to decommission cobalt-60 teletherapy equipment prior to initiating an action. Depleted uranium used as shielding material is also to be treated as radioactive waste. For example, a cobalt-60 teletherapy head may contain depleted uranium and is to be managed appropriately.

(b) The licensee needs to ensure that resources for the disposal of radioactive sources will be made available when the teletherapy equipment is to be decommissioned.

5.4.4.2. Activation products

When equipment used for radiotherapy purposes is decommissioned, the licensee needs to ensure that activated materials from the head of the linear accelerator are correctly disposed of.

The regulatory body may require applicants for a licence to have in place a programme for safe disposal or return of radioactive sources when their use is discontinued, before authorization for the import or purchase of equipment or radiation sources is given. A contract with the manufacturer or a representative for the return of sources is acceptable evidence of such a programme.
5.5. PREVENTION OF ACCIDENTS AND MITIGATION OF THEIR CONSEQUENCES

5.5.1. Safety assessments

To comply with GSR Part 3 [2], requirements for safety assessment (paras 3.29 to 3.36), the registrant or licensee is required to conduct a safety assessment applied to all stages of the design and operation of the veterinary radiation therapy facility.

A report on the safety assessment is to be submitted to the regulatory body if so required. The safety assessment deals essentially with determining ‘what could go wrong’, and how it could be prevented and, in case it does occur, how its consequences could be mitigated.

The safety assessment of potential exposure has to be systematic, has to identify unintended events that could lead to potential exposure, and has to consider their likelihood and potential consequences. Information on events, causes and contributory factors identified from a reported accident is available in Ref. [77]. Reference [77] also includes a review that explores errors of misadministration and novel challenges that arise from the adoption of advancing technologies in veterinary radiation oncology.

The safety assessment not only will cover such events, but also has to be aimed at anticipating other events that have not previously been reported. The safety assessment is required to be documented.

The safety assessment needs to be revised when: (a) new or modified radiation sources are introduced, including equipment and new or renovated facilities; (b) operational changes occur, including changes in workload; (c) operational experience or information on accidents or errors indicates that the safety assessment is to be reviewed.

In safety assessments in veterinary radiation therapy facilities in which brachytherapy or teletherapy with sealed sources is performed, additional steps associated with sealed sources need to be considered. These additional steps include ordering, transport and receipt of sealed sources; unpacking, storage, preparation and handling of the sources prior to their use in the treatment of animals; care of animals with high amounts of activity; storage and handling of sources after removal; and the management of unused radioactive seeds.

To ensure that the safety assessment is comprehensive and is not restricted to past events but also anticipates other possible events, consideration also needs to be given to using systematic techniques, e.g. fault trees and event trees and techniques of probabilistic safety assessment.
For radiation therapy, possible scenarios for potential exposure include flaws in the design of veterinary radiological equipment; failures of veterinary radiological equipment while in operation; failures and errors in software that control or influence the delivery of the radiation; and human error. Potential exposure can arise during imaging, during the preparation of animals, in simulation in treatment planning and during treatment.

As noted earlier, there is currently no radiotherapy equipment designed and manufactured for veterinary use in particular. All equipment used in veterinary radiation therapy is designed for use for medical radiation therapy (i.e. for people).

Information on events, causes and contributory factors identified for reported accidents in medical radiation therapy (i.e. for people) can be found in Ref. [19]. Some of these scenarios could lead to potential exposure in veterinary radiation therapy.

5.5.2. Prevention of accidents

Accident prevention is the best means for avoiding potential exposure, and GSR Part 3 [2], paras 3.39–3.42, establishes requirements for good engineering practice, defence in depth and facility based arrangements to achieve this. Design considerations for veterinary radiological equipment, ancillary equipment and the radiation therapy facility are described in Section 5.2.

5.5.2.1. Behaviour of animals

The behaviour of animals and their unexpected actions can lead to accidents during radiological diagnostic and treatment procedures. All efforts need to be made to minimize accidents involving animals, to include the use of restraint devices, to include practices for keeping exposures ‘as low as reasonably achievable’ and to include measures for sedation. Additionally, animal handlers need to be appropriately trained according to the responsibilities of their work role.

Veterinarians and animal handlers need to be aware of animal behaviours that could affect radiation protection and that could cause unintended incidents. Specific considerations may be necessary to address the prevention of accidents in specific imaging and treatment modalities.

The licensee needs to incorporate measures for defence in depth to cope with events identified by the safety assessment, and measures for evaluation of the reliability of the safety systems (including administrative and operational procedures, equipment and facility design).
This information needs to be incorporated into the education and training, maintenance and quality assurance programmes.

5.5.3. Mitigation of the consequences of accidents

As stated in GSR Part 3 [2], if an event or a sequence of events that has been considered in the assessment of risks (safety assessment) does actually occur, it may be treated either as a planned situation of exposure or, if an emergency has been declared, as an emergency.

On the basis of events identified by the safety assessment for the radiotherapy facility, mitigatory procedures need to be prepared for events associated with potential exposure, including allocation of responsibilities and resources, the development and adoption of procedures, and the provision of training and periodic retraining of the relevant staff in executing the mitigatory measures.

As required in GSR Part 3 [2], para. 3.43, if the safety assessment indicates that there is a reasonable likelihood of an emergency affecting either workers or members of the public, the registrant or licensee is required to prepare an emergency plan.

Emergency arrangements commensurate with the hazard assessed and potential consequences need to be established, as appropriate, in accordance with Refs [38, 39, 78].

As part of the emergency arrangements, responsibilities and resources, emergency procedures, and the provision of training and periodic retraining of the relevant staff in executing the necessary response actions are required to be elaborated.

Since very high doses can be received within seconds and minutes, if an emergency occurs in radiation therapy facility, it is important that the personnel act promptly. Thus, emergency procedures need to include for example, response time objectives, and they need to be regularly tested in exercises.

Workers involved in mitigation of events in radiation therapy or workers engaged in emergency procedures are required to be protected against occupational exposure within the dose limits for occupational exposure in planned situations of exposure.

However, if it is considered justified in an emergency for these dose limits to be exceeded, the workers involved in mitigating the consequences of an event will be considered to be emergency workers, and the requirements and guidance for emergencies established in GSR Part 3, Section 4 [2], GSR Part 7 [39] and the Safety Guide on Occupational Radiation Protection [24] will apply.
As the radiological equipment used in radiotherapy for animals has been designed for radiotherapy in medicine (i.e. for people), the scenarios of incidents that have occurred in radiotherapy in medicine (i.e. for people) [19] need to be considered in the arrangements for management of events in radiotherapy and emergency procedures for veterinary facilities using radiation therapy.

5.5.3.1. **Stuck sources, general**

Mitigatory and emergency procedures need to be short, concise and unambiguous and, if necessary, need to be illustrated with drawings without explanatory text. They need to be able to be read at ‘first sight’ and followed. It needs to be made clear that the first sight procedures refer to actions to be taken immediately to prevent or to limit high exposures, or to take other lifesaving actions [79]. Further actions to recover the sources, and to repair and test the equipment for returning it to use, are not of the same urgency.

In radiation therapy, however, the animal is directly in the radiation beam, and in brachytherapy, sources are placed inside the animal. For this reason, some of the response actions coincide with source recovery actions; for example, the retrieval of remote control brachytherapy sources from the animal to the safe, either manually or electrically or using the manual crank.

5.5.3.2. **Stuck sources, cobalt-60**

Mitigatory and emergency procedures need to be posted at the treatment unit. These procedures need to ensure that the animal is removed from the primary beam as quickly and efficiently as possible while minimizing unnecessary exposure of the personnel involved.

In the case of an event, the first step is to note the time, and then immediately use the source driving mechanism to return the source to the shielded position. If there is an animal on the treatment couch, the animal needs to be removed from the area and the area needs to be secured from further entry. Emphasis needs to be placed on avoiding exposure of personnel to radiation in the primary beam.

The radiation protection officer or qualified expert needs to be notified and needs to take control of the situation, including deciding whether and when it is safe to re-enter the room. Before resuming treatment of the animal, the calibration of the radiation therapy needs to be verified to ensure that it has not changed; in particular, the timer error in cobalt-60 teletherapy units.
Actions are only to be performed only by personnel who are knowledgeable and are trained in the necessary response actions and have regularly participated in drills and exercises.

After the necessary response actions have been taken, the following needs to be done:

(a) An inspection of the machine needs to be performed;
(b) The dose to the animal needs to be assessed and after the ensuing maintenance the use of the machine needs to be cleared;
(c) A record needs to be kept of all actions;
(d) The regulatory body may need to be notified, depending on the country’s regulations;
(e) Medical attention, as necessary, needs to be provided to those involved, commensurate with the doses received [39, 78].

5.5.3.3. Stuck sources, remote control brachytherapy units

The emergency plan needs there to be an emergency container available in the treatment room. There also needs to be an emergency kit containing long handled forceps for manipulation of the source guide tubes, and of the applicators if the source fails to return to the safe.

The emergency container needs to be placed close to the animal and needs to be sufficiently large to accept the entire applicator assembly containing the source that has been removed from an animal. Staff need to be trained in how to implement such a procedure and need to participate in regular drills and exercises.

In high dose rate applications, the short response time necessary for contingency actions (minutes) imposes the need for the immediate availability of trained personnel during all applications. Each of these professionals needs to be educated and trained in emergency procedures and actions.

Manufacturers usually provide suggested emergency procedures if the source fails to return to the safe. It is assumed in the emergency procedures that the physical integrity of the applicator is maintained. These procedures are specific to the actual afterloading unit but generally involve a standard sequence.

After the necessary response actions have been taken, the following needs to be done:

(a) An inspection of the machine needs to be performed;
(b) The dose to the animal needs to be assessed and after the ensuing maintenance, the use of the machine needs to be cleared;
(c) A record needs to be kept of all actions;
(d) The regulatory body may need to be notified, depending on the country’s regulations;
(e) Medical attention, as necessary, needs to be provided to those involved, commensurate with the doses received [39, 78].

5.5.3.4. Incidents and accidents during replacement of sources

Only trained and authorized maintenance or servicing personnel may deal with incidents and accidents during a change of source for external beam therapy and remote control brachytherapy units. If the participation of radiation therapy personnel is necessary for any of these actions, the scope of this participation needs to be limited to operating the equipment. The respective responsibilities of radiation therapy personnel and of maintenance or servicing personnel for these specific situations need to be clearly specified.

5.5.3.5. Incidents and accidents during transport of sources

If the registrant or licensee has an authorization to transport radioactive material, there need to be emergency arrangements in place, in compliance with the requirements of GSR Part 7 [39] and guidelines of the regulatory body.

5.5.3.6. Contamination

In a contamination event, the area needs to be closed to further entry and all those who were in the area need to remain to be surveyed and decontaminated if necessary. If there are windows or ventilation systems, these need to be closed or turned off. The radiation protection officer needs to be contacted immediately once the possibility of contamination is suspected. Contact details for the radiation protection officer need to be posted throughout the radiation therapy facility.

5.5.3.7. Lost radiation therapy sources

A detailed, up to date inventory of all radiation therapy sources needs to be maintained by the radiation protection officer of the veterinary radiation therapy facility. In the event of a lost source, it can then be determined immediately which sources are missing, their type and activity, their last known location, and who last had possession of them.

The area where the sources were last seen needs to be closed to entry and exit until after a survey has been performed. This survey needs to be performed with the most sensitive survey meter for radiation detection that is available in the veterinary radiation therapy facility.
If the source cannot be located and if it is suspected that it may be off the site, the relevant authorities need to be notified and immediate actions are required to be taken in accordance with Refs [39, 40].

5.6. SAFETY IN THE TRANSPORT OF RADIOACTIVE MATERIAL

GSR Part 3 [2], para. 2.25 sets out requirements on the transport of radioactive materials, invoking in particular the IAEA Regulations for the Safe Transport of Radioactive Material, SSR-6 [15].

The Transport Regulations use the defined terms ‘consignor’ to mean any person, organization or government that prepares a consignment for transport, and ‘consignee’ to mean any person, organization or government that is entitled to take delivery of a consignment. ‘Consignment’ is also a defined term, meaning any package or packages, or load of radioactive material, presented by a consignor for transport.

The licensee of a radiation therapy facility may be both a consignee and a consignor, and hence may have responsibilities for both the receipt and the shipment of radioactive sources; for example, sources for external beam radiation therapy and brachytherapy. Shipments may take place when expired radioactive sources need to be returned to the supplier or disposed of off the site, as applicable.

Detailed requirements for the safe transport of radioactive material — including general provisions; activity limits and classification; requirements and controls for transport; requirements for radioactive material, and for packagings and packages; test procedures; and approval and administrative requirements — are established in SSR-6 [15].

Emergency arrangements for the transport of radioactive material need to be put in place, in line with the requirements of GSR Part 7 [39], and the requirements and guidelines of the regulatory body.

The licensee and the radiation protection officer of the radiation therapy facility need to be familiar with these requirements and regulations to ensure that the transport of radioactive material for which they are responsible complies with the requirements and regulations.
Appendix I
PROTECTIVE CLOTHING FOR VETERINARY DIAGNOSTIC RADIOLOGY AND INTERVENTIONAL RADIOLOGY

This appendix describes the protective clothing that can be used in veterinary diagnostic radiology. The radiation protection officer needs to advise the operator of the veterinary facility on the use of such protective clothing, and to advise on which other staff and/or animal handlers need to wear protective clothing during diagnostic procedures. The use of personal protective equipment needs to be included in the operating procedures for the veterinary practice. The following protective clothing can be used:

- Gowns, aprons and thyroid protectors made from a material (such as vinyl) that contains lead;
- Removable bed shielding made from the same material containing lead;
- Gloves or gauntlets made from the same material containing lead;
- Glasses (spectacles) with lenses made from leaded glass or leaded plastic;
- Viewing windows (fixed or mobile) made from leaded glass or leaded plastic.

I.1. GOWNS, APRONS AND THYROID PROTECTORS

Gowns, aprons and thyroid protectors are manufactured in various forms: a coat which is fixed at the front; a poncho which is fixed at the sides; gowns that either are open at the back or contain less lead at the back; or gowns that are in two parts, a top part in the form of a coat and a bottom part that is fixed around the waist.

Protective aprons need to be equivalent to at least 0.25 mm lead if the X ray equipment operates up to 100 kV and 0.35 mm lead if the X ray equipment operates above 100 kV. Interventional radiology staff need to use at least 0.5 mm lead equivalent because of high levels of scattered radiation.

The style of gowns and protective aprons chosen will depend on the radiology practice for which they will be used. It is always better to shield the largest possible area of the body.

In interventional radiology, the thyroid will normally need protection. Some gowns include a collar covering the thyroid, but in most cases a separate thyroid collar will be necessary.
I.2. BED SHIELDING

In interventional radiology, the levels of scattered radiation can be greatly reduced by attaching removable lead vinyl sheets to the side of the X ray table. As the weight is carried by the bed, higher values of lead equivalence can be used.

I.3. LEAD GLOVES OR LEAD GAUNTLETS

Lead gauntlets are heavy gloves made from lead vinyl. They have limited usefulness because they are difficult to use. Their use can increase the length of time needed for a procedure and thus can increase the resulting dose, in some cases. Gauntlets are therefore only to be used where appropriate.

It is possible to obtain lightweight leaded gloves similar to surgical gloves. These need to be used with care, as they contain little lead and are effective only at low tube voltages (less than 60 kVp).

I.4. SPECTACLES

In some interventional radiological procedures, it is possible for the lens of the operator’s eye to receive an annual dose that approaches or even exceeds the dose limit of GSR Part 3 [2] for the equivalent dose to the lens of the eye (20 mSv per year).

In these procedures, some form of eye protection is essential. Glasses (spectacles) that have leaded lenses and eye protection at the sides are one solution.

I.5. VIEWING WINDOWS

Leaded glass or plastic viewing windows are common in shielding for the X ray control area. They need to be marked with their lead equivalence, and the maximum tube voltage (kVp) at which this applies.

For interventional equipment, a movable viewing window is very useful. These are typically mounted on the ceiling and can be placed in such a position that the operator views the main source of scattered radiation (where the X ray beam enters or leaves the animal) through the window. This then provides protection for both the eyes and the thyroid. Frequently, strips of lead vinyl are attached below the window to provide additional protection for the torso.
I.6. QUALITY CONTROL TESTING OF PROTECTIVE EQUIPMENT

All lead vinyl material needs to be tested both soon after purchase and at regular intervals (at least every two years). If vinyl is not stored correctly (on a coat hanger is acceptable) but is folded, for example, it will eventually crack, causing loss of shielding. The damage may not be seen by visual inspection.

All protective lead vinyl materials can be simply tested by fluoroscopy at certain given kVp values. If possible, the fluoroscopy machine needs to be used in manual mode, to avoid damage to the X ray tube. Fluoroscopy screening will not measure the lead equivalence but it will reveal any faults in the shielding. Faulty clothing is to be discarded immediately and not used.

Each item of protective clothing can be given a unique identification, and the details of purchase date and subsequent testing need to be recorded.
Appendix II

INSTRUCTIONS FOR THE RELEASE OF ANIMALS FOLLOWING VETERINARY ADMINISTRATION OF IODINE-131 OR OF COMPOUNDS LABELLED WITH IODINE-131

II.1. IODINE-131 USED IN TREATING THYROID DISEASE: FORM AND ACTIVITY

Iodine-131, in the form of sodium iodide or potassium iodide, is used in treating thyroid disease in animals. It preferably administered systemically, as the oral form might be subject to potential spilling (via spitting or vomiting). The activity used depends on the veterinary indication, varying from 37 MBq (for benign thyroid disease cats) up to 5000 MBq (for malignant thyroid carcinoma) [80].

II.2. EXCRETION OF IODINE-131

Iodine-131 (radioiodine) is excreted primarily via the kidneys and, consequently, the animal needs to be encouraged to drink water to assist excretion. The next most significant pathway for excretion is via the salivary glands. Radioiodine may manifest itself on the skin of an animal owner who touches the mouth area of the animal.

Lesser pathways for excretion and thus for contamination are through sweat and faeces. It is best, if measurements cannot be made, to assume that contamination will occur via all pathways.

The animal therefore needs to be kept confined to a restricted area in the house or backyard away from the family of the owner and away from other pets on release from the veterinary clinic for a period as advised by the veterinarian.

II.3. POLICY FOR THE RELEASE OF ANIMALS

The policy for the release of animals following the administration of iodine-131 needs to comply with local statutory requirements. The release of animals following administration of iodine-131 needs to take into account the circumstances of the owner of the animal and of the family of the owner.

This may include, for example the ages of any children, any pregnancies, any other pets, and the capacity of the owner to clean a restricted area of the house or backyard and to dispose properly of contaminated absorbent material used to line the bottom of the litter box or to clean up vomit, urine and faeces.
Following the release of an animal from a veterinary practice, excretion of unbound iodine-131 will continue for some time. Both contamination and external gamma radiation will therefore be a cause for concern, but they can both be managed if clear instructions are provided to the animal owner.

II.4. ADVICE TO OWNERS ON EXTERNAL IRRADIATION

Provided that measures are taken for the containment of contamination, external irradiation will be the most important safety related issue. Persons at risk of external exposure include the animal owner, the family of the animal owner and members of the public. The following measures to be taken by the animal owner will provide protection for these groups:

(a) It is advisable to avoid transporting the animal on public transport. If public transport has to be used, journey times need to be limited to less than two hours. The separation of the animal from passengers needs to be maximized.

(b) The animal needs to be confined to a restricted area inside the house or in the back yard of the house. The owner needs to maintain a distance of at least an arm’s length, and preferably at least one metre, from the animal for short periods of contact. For longer periods, the owner needs to maintain a distance of at least 2 metres from the animal.

(c) Contact between the animal and children needs to be avoided.

(d) Contact between the animal and pregnant women needs to be avoided.

Once excretion of iodine-131 is effectively finished, the external radiation will decline with the effective half-life, which in the case of iodine-131 is taken to be equal to 2–3 days [81].

II.5. ADVICE TO OWNERS ON CONTAMINATION

The following practical steps need to be followed as a precaution to minimize contamination. They are to be followed for at least one week, but for a period of time that
depends on the residual activity present at release of the animal and the consequent dose rates. In addition, the steps will need to be reviewed.

The members of the family of the owner, e.g. any children and their number and ages, and any women who are or who may be pregnant, need to be taken into consideration.

The circumstances in which the animal is living, in particular with regard to sanitary arrangements, also need to be considered.

Urinary excretion by the animal is to be promoted by frequent intake of fluids. Owners are to wash their hands after touching the animal. The owner needs to wear gloves while cleaning the restricted area of the house or the back yard that houses the animal, and needs to wash hands after cleaning has been completed.

Absorbent material, including cat litter, used to line the litter box that has been contaminated with vomit, urine and faeces, needs to be collected for at least two weeks after the animal has been released from the veterinary practice and needs to be stored in double garbage bags at a remote place (e.g. in a garage or a garden shed) for at least three months.

II.6. ADVICE TO OWNERS ON EMERGENCIES

In case of illness of a treated animal requiring the attendance of the animal at a veterinary practice, those involved at the veterinary practice need to be notified of the therapy carried out, and of the date, the radionuclide and the activity involved. Such information is to be included in the information card given to the owner on the release of the animal.
Appendix III

PROCEDURES FOR DEALING WITH SPILLS OF RADIOACTIVE MATERIAL
AND WITH DECONTAMINATION OF PERSONS IN A VETERINARY
RADIATION FACILITY

III.1. SPILLAGE OF SMALL AMOUNTS OF RADIOACTIVE MATERIAL

After a spillage of a small amount of radioactive material — for example, low volumes of non-toxic radiopharmaceuticals that are easily removed — the following actions need to be taken after contacting the radiation protection officer:

(a) Use protective clothing and disposable gloves.

(b) Quickly blot the spill with an absorbent pad to keep it from spreading.

(c) Remove the pad from the spill.

(d) Wipe the surface with a tissue, wiping from the edge of the contaminated area towards the centre.

(e) Monitor the tissue for residual activity, for example by using a contamination monitor or by performing a wipe test for residual activity on a tissue.

(f) Continue the cycle of cleaning and monitoring until the measurements indicate that the spill has been removed. Try to keep the volume of contaminated waste as small as possible.

(g) In some cases, such as with short lived radionuclides, it may be simpler to ‘quarantine’ the area for sufficient time to allow decay. This may be done by covering the spill site, e.g. with plastic sheets, and if necessary by preventing access to the area.

(h) Use a plastic bag to hold contaminated items. Suitable bags, as well as damp paper towels, need always to be kept available.

(i) Monitor all people involved in the spill for contamination on their leaving the room; in particular, monitor people’s shoes if the spill was on the floor.

III.2. SPILLAGE OF LARGE AMOUNTS OF RADIOACTIVE MATERIAL

After a spillage of a large amount of radioactive material, for example if an animal urinates outside a kennel or stable, the following actions need to be taken:

(a) Throw absorbent pads or other absorbent material (such as cat litter or wood shavings) over the spill to prevent the spread of contamination.

(b) Evacuate people not involved in the spill from the area immediately.

(c) Inform the radiation protection officer immediately of the need to directly supervise the
cleanup.

(d) Monitor all people involved in the spill for contamination on their leaving the room.
(e) When necessary, perform a thyroid bioassay.
(f) If clothing is contaminated, remove it and place it in a plastic bag labelled ‘RADIOACTIVE’.
(g) If contamination of skin occurs, wash the area immediately.
(h) If contamination of an eye occurs, flush with large quantities of water.
(i) Once the contamination has been contained, the procedures already outlined for cleaning small spills may be followed. Particular care needs to be taken that contaminated waste bags are appropriately labelled and stored.
(j) Restrict the entry to the contaminated area until decontamination has been finalized and the area has been released by the radiation protection officer.
Typical radiation safety features for rooms used for the storage, preparation and implantation of sealed radioactive sources for manual and low dose rate brachytherapy include the following:

- The rooms are provided with a lockable door to control access and to maintain security of sources.
- For storage of sources, a shielded safe made of fireproof materials is located near the preparation workbench to reduce the exposure of personnel during the handling and transfer of sources, if applicable.
- The safe needs to have compartments for different source activities. Each compartment needs to be marked so as to permit immediate and easy identification of its contents from the outside with a minimum of exposure.
- Sources need to be readily identifiable by sight. When radioactive sources of the same appearance but of different activities or activity distribution are used, they need to be clearly distinguishable, e.g. by means of threads or beads of different colours.
- The workbench needs to be provided with L-block shielding, a lead glass viewing window and a magnifying glass.
- The working surface for source preparation needs to be smooth and seamless to help avoid losing small sources.
- The source handling area needs to be well illuminated. A magnifying glass in a fixed mounting needs to be available for viewing sources, so as to handle sources efficiently and with a minimum of radiation exposure.
- Devices for handling and threading sources, typically forceps, will be available. The devices need to be as long as practicable, compatible with efficient source handling.
- The source storage and preparation laboratory have a sink with a filter or trap to prevent sources being lost into the sewerage system.
- There has to be a clear indication of the radiation level in terms of ambient dose equivalent. This is achieved either by an area radiation monitor that is visible on entering the room and during any handling of the unshielded sources, or by a survey meter that is
available and in use during source handling.

- Hand carried transport containers are provided with long handles. The lid of the container is securely fastened to prevent tipping and dropping of sources during transport. Containers bear the radiation symbol as well as a warning sign.
- Space needs to be available for trolleys that are used for transporting sources.
REFERENCES


[52] INTERNATIONAL ELECTROTECHNICAL COMMISSION, IEC 60601-2-11, Edition 3.0, Medical Electrical Equipment, Part 2-11: Particular Requirements for the


[63] INTERNATIONAL ELECTROTECHNICAL COMMISSION, IEC 60601-2-17, Edition 3.0, Medical Electrical Equipment, Part 2-17: Particular Requirements for the


Annex

GUIDELINES OF THE HEADS OF THE EUROPEAN RADIOLOGICAL PROTECTION COMPETENT AUTHORITIES (HERCA GUIDELINES):
GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF VETERINARY PROFESSIONALS

A-1. INTRODUCTION

This document deals with the education and training requirements of all veterinary professionals such as the veterinarians, the veterinary radiographers and veterinary assistants. The education and training requirements in this document have been formulated as learning outcomes in terms of knowledge, skills and competences for the professionals concerned. This model has been proposed by the European Commission and has also been used by the “MEDRAPET”-project, which dealt with education and training requirements for the different professionals involved in human medicine applications of ionizing radiation. The “MEDRAPET”-project results have meanwhile been published as number 175 of the EC’s Radiation Protection Series (RP): Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union, on which current document is largely based and inspired.

The learning outcomes are divided into two separate levels of education and training. The core learning outcomes should be attained by all veterinary professionals performing or assisting in procedures using ionizing radiation. Certain practices, such as when performing nuclear medicine, radiotherapy or interventional radiology procedures, imply specific or greater risks and therefore call for additional education and training, which are dealt with in the additional learning outcomes.

The education and training requirements included in the tables that follow were developed in accordance with the graded approach principle. They therefore take into account the radiation risks associated with the different types of procedures they concern. These requirements have to be met before the veterinary professionals start to work with ionizing radiation for diagnostic or therapeutic purposes. Once they have achieved the suggested level of knowledge, skills and competences (KSC), they should refresh and update their radiation protection KSC at regular

7 Reproduced verbatim and in full, with the permission of the Heads of the European Radiological Protection Competent Authorities (HERCA).
8 ‘Should’ statements are recommendations of HERCA; they are not recommendations of the IAEA.
time intervals in order to keep abreast of the continuous changes resulting from advances in science and technology and the related evolution of practice.

This document does not specify any education and training requirements for owners or handlers of the animal, who could be present during -or even actively take part in- a procedure. These people are not considered as professionally exposed personnel, but as members of the public, taking into account all related radiation protection requirements that apply where the procedures are performed. If the veterinary radiological practitioner judges that the presence of such persons is justifiable, then prior to the exposure taking place they should be informed on the possible radiological risks they would expose themselves to, and should be offered the free choice to accept these risks or not. If they chose to stay present or to actively assist, then they need to be instructed on how to behave in order to keep exposures ALARA.

Particular attention should be paid to the fulfilment of all radiation protection requirements mentioned above if children are concerned or women of childbearing age whose pregnancy cannot be excluded, or breastfeeding women in the case of nuclear medicine procedures. Local rules and regulations may prohibit the presence of these vulnerable population subgroups. It is possible to further formalize this, by having the owner/handler sign an informed consent form which states that they have, prior to the onset of the procedure, been informed about the risks of exposure and on how to behave as to reduce these risks to the extent practicable.

The physical environment in which veterinary procedures involving ionizing radiation are performed may vary and this may have an impact on the related risks. For that reason in the tables hereafter a distinction has sometimes been made between procedures performed in the well-controlled environment of the veterinary clinic or practice, referred to as “on site” and procedures done elsewhere, for instance in a stable or outside in the field, referred to as “off-site”.

A-2. RADIATION PROTECTION EDUCATION AND TRAINING REQUIREMENTS FOR VETERINARY DOCTORS

This chapter deals with the education and training requirements of the veterinarians, working with ionizing radiation.

The core learning outcomes that are dealt with in the first table underneath should be attained by all veterinarians. Most and for all, they must be able to deal with possible radiation exposure risks implied by the use of ionizing radiation in procedures they perform themselves, which a large majority do.
But all, even those who don’t perform such procedures themselves, should have some awareness of the risks, their magnitude and their possible specific characteristics (such as in nuclear medicine) for procedures they refer their animal patients to.

They should also know the basics of how to protect against these risks, understand the principles of justification, optimization and dose limitation and be able to apply these principles in veterinary practice.

The veterinarians also play a key role in informing their staff and the owners/handlers of the animals on the risks related to the use of ionizing radiation.
### TABLE A-1. CORE LEARNING OUTCOMES IN RADIATION PROTECTION FOR VETERINARY DOCTORS

<table>
<thead>
<tr>
<th>Knowledge on the physical interaction principles of radiation with matter (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)</th>
<th>Core radiation protection for all veterinary doctors</th>
<th>Skills (cognitive and practical)</th>
<th>Competence (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1. The different natural and artificial radiation sources and their relative contribution to exposure of the population</td>
<td></td>
<td>S1. Identify the legal radiation protection obligations in daily practice</td>
<td>C1. Implement the national radiation protection regulatory requirements in daily practice: identify flaws in implementation and correct where needed</td>
</tr>
<tr>
<td>K2. The fundamental characteristics of radioactivity and the different radiation types emitted</td>
<td></td>
<td>S2. Apply state of the art practical radiation protection measures with emphasis on minimizing exposures to staff and owners/handlers (sedation, cassette holders, …), taking safety issues into account</td>
<td>C2. Take full responsibility for the justification and optimization of procedures that require the use of ionizing radiation performed by oneself or under one’s authority, both on site within the practice and in particular when ionizing radiations are used off-site</td>
</tr>
<tr>
<td>K3. The physical characteristics of X-rays and their use in imaging systems</td>
<td></td>
<td>S3. Communicate the most important factors that influence staff doses, in particular understand the impact of stray radiation correct positioning and limiting the number of persons involved</td>
<td>C3. Take responsibility for the justification of procedures referred for more advanced imaging of therapy procedures implying the application of ionizing radiation based on contemporary scientific information and indications for their use</td>
</tr>
<tr>
<td>K4. The fundamentals of radiation detection</td>
<td></td>
<td>S4. Compare reported staff doses to background doses and communicate about possible associated risks in comparison to other risks in daily life, in particular to (possibly) pregnant staff members</td>
<td>C4. Provide information to personnel and owners regarding risks and benefits of the radiographic procedures</td>
</tr>
<tr>
<td>K5. The fundamental radiological quantities and units</td>
<td></td>
<td>S5. Estimate the dose received by non-professionals assisting in procedures and communicate about possible associated risks in particular to (possibly) pregnant women</td>
<td></td>
</tr>
<tr>
<td>K6. The basics of the biological effects of radiation</td>
<td></td>
<td>S6. Communicate about specific risks of nuclear medicine procedures and the protection principles that apply</td>
<td></td>
</tr>
<tr>
<td>K7. The basic principles of veterinary applications of nuclear medicine -both diagnostic and therapeutic- and the associated risks to staff and public</td>
<td></td>
<td>S7. Perform required quality assurance</td>
<td></td>
</tr>
<tr>
<td>K8. The differences between deterministic and stochastic effects and their respective dose ranges for doses received by the personnel and owners</td>
<td></td>
<td>S8. Apply the protection principles of time, distance, shielding correctly</td>
<td></td>
</tr>
<tr>
<td>K12.</td>
<td>The general regulations relevant to radiation protection in the veterinary sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K13.</td>
<td>The regulatory requirements that apply for a practice with regard to the site, the equipment and its Quality Control, the Quality Assurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K14.</td>
<td>The fundamentals of protection by limiting exposure time, taking distance and shielding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K15.</td>
<td>The radiation protection aspects with respect to owners or other laypersons taking part in the radiological procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K16.</td>
<td>The radiation protection aspects with respect to staff and their unborn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K17.</td>
<td>The principles of quality control and quality assurance with respect to radiation protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K18.</td>
<td>The specific radiation protection issues of working off-site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K19.</td>
<td>The risks associated with transportation and handling of the X-ray device and required quality assurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K20.</td>
<td>The phenomenon of accidental/unintended exposures and how to manage these</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| S9. | Optimize the choice of the site and set-up when working off-site, delineate controlled/supervised area |
| S10. | Correctly inquire about possible pregnancy |
### TABLE A-2. ADDITIONAL LEARNING OUTCOMES FOR VETERINARY DOCTORS WORKING IN THE FIELD OF NUCLEAR MEDICINE

<table>
<thead>
<tr>
<th>Knowledge (facts, principles, theories, practices)</th>
<th>Skills (cognitive and practical)</th>
<th>Competence (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1. The regulatory framework governing the practice of nuclear medicine in your country</td>
<td>S1. For each diagnostic or therapeutic procedure, apply European and national regulations, recommendations and standards related to staff safety, owner/handler and environmental safety</td>
<td>C1. Take responsibility for the justification of every nuclear medicine procedure</td>
</tr>
<tr>
<td>K2. The requirements for regulatory compliance with respect to the management and use of sealed and unsealed sources; including requirements for storage, shielding, record-keeping, waste management, transport and audit</td>
<td>S2. Develop an organizational policy for the safe handling of unsealed radionuclides (e.g. storage, shielding, record keeping, transportation, and waste)</td>
<td>C2. Take responsibility for compliance with regulatory requirements and ALARA principles concerning occupational and public radiation exposures, including the risk to pregnant and/or breastfeeding owners/handlers</td>
</tr>
<tr>
<td>K3. The relevant regulations concerning treatment of animals on an in-patient/outpatient basis, as well as their release criteria, where applicable</td>
<td>S3. Develop an organizational policy to keep doses to personnel from external and internal (inhalation, ingestion) exposure ALARA</td>
<td>C3. Take responsibility for optimizing the administration of the radiopharmaceutical and the activity used for a given diagnostic or therapeutic procedure based on case-specific information</td>
</tr>
<tr>
<td>K4. The justification aspects, in particular when considering off-site procedures</td>
<td>S4. Apply the principles of justification (risk/benefit assessment), optimization (ALARA) and dose limitation</td>
<td>C4. Develop and implement SOPs for all specialized procedures performed regularly</td>
</tr>
<tr>
<td>K5. The basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)</td>
<td>S5. Decide on radiopharmaceuticals and procedures to be used</td>
<td>C5. Take responsibility for dealing with incidents/accidents/events</td>
</tr>
<tr>
<td>K6. The concepts and tools for scaling administered activity depending on animal size/weight</td>
<td>S6. Apply the basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)</td>
<td>C6. Advise owners on the risks and benefits of a planned nuclear medicine procedure by using oral and written information and instructions</td>
</tr>
<tr>
<td>K7. The principles and process steps involved in the administration of the different forms of radiopharmaceuticals applied</td>
<td>S7. Develop organizational policies for the optimization of staff exposures in all specialized procedures</td>
<td>C7. Provide oral and/or written instructions to owners/handlers of animals that have been submitted to therapeutic nuclear medicine procedures</td>
</tr>
<tr>
<td>K8. The actions that should be taken after misadministration and accidental/unintended contamination</td>
<td>S8. Design appropriate safety measures for management of animals that are submitted to therapeutic nuclear medicine procedures including release criteria when working on-site and specific safety requirements when working off-site</td>
<td></td>
</tr>
</tbody>
</table>
metabolism of radiopharmaceuticals as sources of internal and external radiation exposure for staff and for members of the public

K10. The quantitative dose assessment and estimation of risk for staff and for members of the public, where applicable

K11. The dose limits for professionally exposed workers (including organ doses), for pregnant workers and for members of the general public, such as for owners/handlers

K12. The procedures with potentially high doses for extremities and eye lenses, such as the use of high-energy beta emitters.

K13. The relevant occupational radiation protection issues associated with all specialized procedures performed, e.g. radio-synovectomy, targeted therapies with alpha or beta emitters

S9. Explain, where applicable, the estimated dose and the corresponding risk for members of the public, exposed/potentially exposed as a result of nuclear medicine procedures

S10. Estimate the total dose to the owner and/or handler

S11. Identify the required instructions for owners and handlers for minimizing exposure (external and internal)

S12. Deal with and/or solve incidents, accidents, events, contaminations

S13. Identify procedures that require special operational protection, e.g. extra shielding, remote handling or specific dose monitoring, e.g. finger dosimeters or incorporation monitoring

S14. Apply for ethical and legal approval of exposure in medical research, where applicable

S15. Apply the transport regulation (ADR) with respect to radioactive substances

C8. As legal person responsible for the undertaking, assume responsibility for implementing an organizational policy for protecting pregnant and breastfeeding workers from exposure risks in controlled areas

C9. As legal person responsible for the undertaking, assume responsibility for communicating on worker radiation protection / the organization policy for staff protection

C10. As legal person responsible for the undertaking, assume responsibility for implementing a monitoring programme for external and internal exposures of workers commensurate with the procedures performed and the corresponding risks
### TABLE A-3. ADDITIONAL LEARNING OUTCOMES FOR VETERINARY DOCTORS WORKING IN THE FIELD OF RADIOTHERAPY

<table>
<thead>
<tr>
<th>Knowledge (facts, principles, theories, practices)</th>
<th>Skills (cognitive and practical)</th>
<th>Competence (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1. The interaction of radiation at the molecular level and the effects of oxygen, sensitizers and protectors</td>
<td>S1. Apply your knowledge of clinical and radiological anatomy, physics and biology to diagnosis and therapy decision making</td>
<td>C1. Consult owners/handlers on radiotherapy and ensure follow up of treatment response</td>
</tr>
<tr>
<td>K2. The cellular effects, mechanisms of cell death and cell survival curves</td>
<td>S2. Apply treatment planning including 3D planning and virtual and CT simulation. Apply these procedures to plan animal treatments</td>
<td>C2. Recommend appropriate dose and fractionation schedule for curative and palliative external beam radiotherapy and brachytherapy</td>
</tr>
<tr>
<td>K3. DNA damage and the repair of radiation damage</td>
<td>S3. Evaluate the benefits of conformal and special radiotherapy techniques if available (IORT, stereotactic radiotherapy)</td>
<td>C3. Audit an external beam radiotherapy/brachytherapy treatment plan in collaboration with physicists, radiographers and other veterinary professionals and be aware of the consequences of one’s actions and those of others</td>
</tr>
<tr>
<td>K4. The radiosensitivity of normal tissue systems and organs</td>
<td>S4. Apply algorithms for dose calculations</td>
<td>C4. Assess the risk of an external beam radiation therapy and brachytherapy treatment plan</td>
</tr>
<tr>
<td>K5. Tumorigenesis and leukaemogenesis</td>
<td>S5. Examine treatment options in the light of the prognosis</td>
<td>C5. Engage in planning using IMRT and other techniques such as stereotactic, particle and IGRT, if available</td>
</tr>
<tr>
<td>K6. The effect of time-dose fractionation, Linear Energy Transfer (LET), different radiation modalities and the interaction between cytotoxic therapy and radiation</td>
<td>S6. Develop an evidence-based treatment strategy and assess patients for curative and palliative external beam radiotherapy and brachytherapy</td>
<td>C6. Authorize a radiotherapy treatment</td>
</tr>
<tr>
<td>K7. The atomic and nuclear structure</td>
<td>S7. Analyse and synthesize research evidence to change practice</td>
<td>C7. Assess animals for combined modality therapy</td>
</tr>
<tr>
<td>K8. Radioactive decay</td>
<td>S8. Develop a radiotherapy treatment strategy and technique</td>
<td>C8. Take clinical responsibility for the delivery of radiation therapy together with systemic agents (and where necessary to work in collaboration with other specialists involved in systemic therapies) on an in-patient or out-patient basis</td>
</tr>
<tr>
<td>K9. Radioisotopes</td>
<td>S9. Adapt treatment plans according to the animal’s individual needs, pre-morbid conditions, toxicity of radiotherapy and systemic treatments</td>
<td></td>
</tr>
<tr>
<td>K10. Radiation transport in tissues</td>
<td>S10. Assess and manage animals undergoing external beam radiotherapy and brachytherapy</td>
<td></td>
</tr>
<tr>
<td>K11. The mechanisms of operation of the used equipment (X-ray tube, …)</td>
<td>S11. Adapt course of radiotherapy treatment for individual animals according to severity of reactions, including adjustment for gaps in treatment</td>
<td></td>
</tr>
<tr>
<td>K13. Target absorbed dose specification in external radiotherapy</td>
<td>S13. Investigate accidental/unintended exposures</td>
<td></td>
</tr>
<tr>
<td>Radiotherapy (IGRT), stereotactic radiotherapy and particle therapy</td>
<td>K17. The risk of possible side-effects (deterministic effects and secondary tumours, etc.)</td>
<td>K18. Radiation weighting factor</td>
</tr>
<tr>
<td>———</td>
<td>——</td>
<td>——</td>
</tr>
<tr>
<td></td>
<td>C9. Take responsibility for the clinical implications and procedures of brachytherapy using sealed and unsealed sources</td>
<td>C10. Engage in QA and follow safety policies</td>
</tr>
</tbody>
</table>
### TABLE A-4. ADDITIONAL LEARNING OUTCOMES FOR VETERINARY DOCTORS WORKING IN THE FIELD OF INTERVENTIONAL RADIOLOGY

<table>
<thead>
<tr>
<th><strong>Knowledge</strong> (facts, principles, theories, practices)</th>
<th><strong>Skills</strong> (cognitive and practical)</th>
<th><strong>Competence</strong> (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1. The specific requirements of image acquisition and image quality aspects with respect to fluoroscopy</td>
<td>S1. Application of radiation physics to optimize interventional protocols, obtaining desired procedure outcome(s) while minimizing exposure</td>
<td>C1. Choice of the best interventional equipment for your animal patient range, taking into account the resources available</td>
</tr>
<tr>
<td>K2. The detailed understanding of the following features of fluoroscopes: flat-panel/image-intensifier detectors (including problems with image intensifiers such as geometric distortion, environmental magnetic field effects), continuous and pulsed acquisition (including frame rate), automatic brightness control, high-dose rate fluoroscopy, cine runs, last image hold, road mapping</td>
<td>S2. Application, on a daily basis, of all technical features and capabilities of the available equipment that allow quality-improvement and dose-reduction</td>
<td>C2. Provision of advice to owners/handlers on the radiation-related risks and on the expected benefits of a planned interventional procedure</td>
</tr>
<tr>
<td>K3. The radiobiological dose-effect relationships relevant to interventional radiology with respect to staff, public and animal safety, including discussion of the physical and biological background; response of tissues to radiation on molecular, cellular and macroscopic level; deterministic effects in particular on skin and lens of the eye, models of radiation-induced cancer risk, hereditary risks; and radiation effects on adults, children and unborn.</td>
<td>S3. Ability to recognize acute radiation skin effects and, where needed, adequately treat them</td>
<td>C3. Assumption of responsibility for justification of radiation exposure in every individual interventional radiology procedure</td>
</tr>
<tr>
<td>K4. The principle of ALARA and its applicability to interventional radiology settings</td>
<td>S4. Application of optimized procedure protocols by using SOPs for interventional radiology and by adapting these to the specific characteristics of the animal</td>
<td>C4. Assumption of responsibility for optimizing the technique/protocol used for a given interventional procedure based on animal-specific characteristics and needs</td>
</tr>
<tr>
<td></td>
<td>S5. Choice of the best compromise between risk-benefit ratio (image quality and procedure outcome vs radiation exposure) on a case-by-case basis</td>
<td>C5. Assumption of responsibility for avoiding, where feasible, very high doses to the skin, which could cause deterministic effects</td>
</tr>
<tr>
<td></td>
<td>S6. Supervision of the use of personal protective equipment by interventional staff, support in the monitoring of the workplace and individual exposure assessment, investigation and follow up, health surveillance and related recording</td>
<td>C6. Follow-up of animals to check for the appearance of deterministic effects</td>
</tr>
<tr>
<td></td>
<td>S7. Application of and advise on the use of radiation protection measures in interventional radiology, particularly for the hands and the eyes</td>
<td>C7. Assumption of responsibility for and establishment of procedures to ensure limitation of dose to staff and,</td>
</tr>
<tr>
<td>K5. The meaning of justification and optimization as applied to interventional radiology practices</td>
<td>S8. Recognition of cases of high skin doses which may require specific follow-up</td>
<td>where applicable, to members of the public</td>
</tr>
<tr>
<td>K6. The concepts and tools for dose management in interventional radiology with respect to staff, members of the public and animals</td>
<td>S9. Computational estimation of risk to staff and, where applicable, to members of the public, starting from measurement data</td>
<td>C8. Assumption of responsibility for procurement of images of sufficient quality for the clinical purpose, while minimizing staff exposure</td>
</tr>
<tr>
<td>K8. The methods and tools for dose management in interventional radiology</td>
<td>S11. Development of an organizational policy to keep doses to interventional radiology staff ALARA</td>
<td></td>
</tr>
<tr>
<td>K9. The basic concepts exposure measurement and computational dose estimation in interventional radiology</td>
<td>S12. Able to find and apply the relevant regulations for any clinical situation in interventional radiology</td>
<td></td>
</tr>
<tr>
<td>K10. The key considerations relevant to radiation protection when designing an interventional radiology unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K11. The expected doses (to staff and, where applicable, to members of the public, to reference animal for the main interventional radiology procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K12. The quantitative risk and dose assessment for workers (and public, where applicable) in interventional radiology</td>
<td></td>
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</tr>
<tr>
<td>K13. The ability to define quality assurance in interventional radiology, to explain its management and to assign responsibilities.</td>
<td></td>
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<tr>
<td>K14. The ability to list the key components of image quality and their relation to procedural staff and animal patient exposure</td>
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<tr>
<td>K15.</td>
<td>The regulatory framework relevant to the practice of veterinary interventional radiology in the country of practice</td>
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This chapter deals with the education and training requirements of the veterinary radiographers and veterinary assistants, working with ionizing radiation.

Veterinary radiographers or assistants are veterinary professionals that actively partake in the care of animals, but do not qualify as veterinarians. Depending on the specific country and the education system, these professionals go by different names. They work under the supervision and responsibility of a veterinarian and can be involved in procedures using ionizing radiation. In this latter case, they need to have an appropriate level of education and training in order to perform their job in a safe manner.

Most and for all, they must be able to deal with possible radiation exposure risks implied by the use of ionizing radiation in procedures they perform themselves.

But all, even those who don’t perform such procedures themselves, should have some awareness of the risks, their magnitude and of their possible specific characteristics (such as in nuclear medicine) for procedures they assist in doing. They should also know the basic rules of how to protect against these risks.

Attention should be paid as to keep the education and training packages for these persons very practice-oriented and adequately limited in volume to be practicable, in particular for those who don’t perform procedures themselves.

In contrast to the education and training requirements for veterinarians, not all requirements in this document necessarily need to be attained by all veterinary radiographers or assistants. Depending on their scope of practice and the degree of autonomy they have in the different countries, the level of education and training may differ. Therefore, countries may choose to omit some of the requirements.

Although certain countries give their veterinary assistants/radiographers a high level of autonomy and responsibility, it is preferable that higher risk diagnostic or treatment procedures should be performed by the veterinarians themselves. This does not imply that a veterinary assistant or radiographer can’t take an active part in these procedures. Examples of such higher risk diagnostic procedures or treatments are interventional radiology and radiotherapy including nuclear medicine treatment procedures.
TABLE A-5. CORE LEARNING OUTCOMES IN RADIATION PROTECTION FOR VETERINARY RADIOGRAPHERS AND VETERINARY ASSISTANTS

<table>
<thead>
<tr>
<th>Knowledge on the physical interaction principles of radiation with matter (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)</th>
<th>Skills (cognitive and practical)</th>
<th>Competence (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>K1.</strong> The different natural and artificial radiation sources and their relative contribution to exposure of the population</td>
<td>S1. Use the appropriate medical devices in an effective, safe and efficient manner</td>
<td>C1. Practice effectively, accurately and safely, while taking into account guidance of legal, ethical and professional frameworks.</td>
</tr>
<tr>
<td><strong>K2.</strong> The fundamental characteristics of radioactivity and the different radiation types emitted</td>
<td>S2. Identify the legal radiation protection obligations in daily practice</td>
<td>C2. Take responsibility for the optimization of procedures implying the application of ionizing radiation performed by oneself autonomously or under one’s authority, in particular when off-site, if applicable (for the tasks you are entrusted to perform by the veterinarian).</td>
</tr>
<tr>
<td><strong>K3.</strong> The physical characteristics of X-rays and their use in imaging systems</td>
<td>S3. Apply radiation protection measures in daily practice, including when accidental/unintended exposures occur</td>
<td>C3. Avoid unnecessary exposure and minimize necessary exposure as part of optimization.</td>
</tr>
<tr>
<td><strong>K4.</strong> The fundamentals of radiation detection</td>
<td>S4. Communicate the most important factors that influence colleagues, owners and handlers doses, in particular understand the impact of stray radiation and positioning of persons involved</td>
<td>C4. Carry out work in a safe manner when using ionizing radiation, taking into account current safety standards, guidelines and regulations.</td>
</tr>
<tr>
<td><strong>K5.</strong> The fundamental radiological quantities and units</td>
<td>S5. Perform required quality assurance</td>
<td>C5. Participate in the process of creating and guaranteeing maximum safety for oneself, others and the animal involved, during examinations/treatments involving ionizing radiation and apply the ALARA principle.</td>
</tr>
<tr>
<td><strong>K6.</strong> The basics of the biological effects of radiation</td>
<td>S6. Apply the protection principles of time, distance, shielding correctly</td>
<td>C6. Notify the responsible practitioner, if a request or referral in one’s professional opinion, is dangerous or inappropriate.</td>
</tr>
<tr>
<td><strong>K7.</strong> The relation between effective dose and the risk of cancer and hereditary effects</td>
<td>S7. Optimize the choice of the temporary sites and set-up when working off-site, delineate controlled/supervised area, if applicable</td>
<td></td>
</tr>
<tr>
<td>K12.</td>
<td>The fundamentals of protection by limiting exposure time, taking distance and shielding</td>
<td></td>
</tr>
<tr>
<td>K13.</td>
<td>The occupational risks to health and safety that may be encountered such as safe moving and handling of animals and equipment</td>
<td></td>
</tr>
<tr>
<td>K14.</td>
<td>The radiation protection aspects with respect to owners or other laypersons and their unborn children when taking part in the radiological procedures</td>
<td></td>
</tr>
<tr>
<td>K15.</td>
<td>The principles of quality control and quality assurance with respect to radiation protection</td>
<td></td>
</tr>
<tr>
<td>K16.</td>
<td>The specific radiation protection issues of working off-site</td>
<td></td>
</tr>
<tr>
<td>K17.</td>
<td>The risks associated with transportation and handling of the mobile X-ray device and the commensurate quality assurance requirements</td>
<td></td>
</tr>
<tr>
<td>K18.</td>
<td>The phenomenon of accidental/unintended exposures</td>
<td></td>
</tr>
<tr>
<td>S10.</td>
<td>Recognize the complicated situation pertaining to radiation protection regarding scientific knowledge on the one side and societal concern and personal emotions on the other side</td>
<td></td>
</tr>
<tr>
<td>S11.</td>
<td>Identify different image quality standards for different techniques</td>
<td></td>
</tr>
<tr>
<td>S12.</td>
<td>Apply the concepts and tools for radiation protection optimization</td>
<td></td>
</tr>
<tr>
<td>C7.</td>
<td>Recognize the limitations of one’s own scope of competence and seek advice and guidance accordingly</td>
<td></td>
</tr>
<tr>
<td>C8.</td>
<td>Recognize the radiation hazards associated with one’s work and take measures to minimize them</td>
<td></td>
</tr>
<tr>
<td>C9.</td>
<td>Monitor radiation exposure with the use of a personal dosimeter</td>
<td></td>
</tr>
<tr>
<td>C10.</td>
<td>Establish safe working conditions according to the recommendations and the statutory requirements of European, national, regional legislation, where applicable</td>
<td></td>
</tr>
<tr>
<td>C11.</td>
<td>Inform and instruct other personnel, handlers, owners and persons of the public present or participating in matters relating to appropriate radiation protection practices</td>
<td></td>
</tr>
<tr>
<td>C12.</td>
<td>Place radiation risks in relation to other risks within a societal context</td>
<td></td>
</tr>
<tr>
<td>C13.</td>
<td>Reflect on one's own radiation risk perception</td>
<td></td>
</tr>
<tr>
<td>C14.</td>
<td>Evaluate the results of routine quality assurance tests</td>
<td></td>
</tr>
<tr>
<td>Knowledge (facts, principles, theories, practices)</td>
<td>Skills (cognitive and practical)</td>
<td>Competence (responsibility and autonomy)</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>K1. The physical principles of how radionuclides can be generated</td>
<td>S1. For each diagnostic or therapeutic procedure, apply European and national regulations, recommendations and standards related to staff, owner/handler and environmental safety</td>
<td>C1. Take responsibility for conforming to national regulations for all handling of unsealed radioactive substances.</td>
</tr>
<tr>
<td>K2. The possibilities to physically shield radionuclides</td>
<td>S2. Apply the principles of justification (risk / benefit assessment), optimization (ALARA) and dose limitation</td>
<td>C2. Take responsibility for conforming to local standards and standard SOPs while handling unsealed radioactive substances</td>
</tr>
<tr>
<td>K3. The relevant occupational radiation protection issues associated with all specialized procedures performed</td>
<td>S3. Translate guidance and local rules into practical working routines so as to minimize dose to colleagues</td>
<td>C3. Take responsibility for the optimization of every nuclear medicine procedure</td>
</tr>
<tr>
<td>K4. The regulatory framework governing the practice of nuclear medicine in your country</td>
<td>S4. Perform and interpret quality control tests to determine whether nuclear medicine equipment is within manufacturer specification</td>
<td>C4. Take responsibility for interpreting QC tests to determine whether nuclear medicine equipment is within manufacturer specification</td>
</tr>
<tr>
<td>K5. The requirements for regulatory compliance with respect to the management and use of sealed and unsealed sources; including requirements for storage, shielding, record-keeping, waste management, transport, quality assurance and audit.</td>
<td>S5. Use devices which can be used to monitor and also minimize radiation dose</td>
<td>C5. Comply with good manufacturing practice when working in the radiopharmacy</td>
</tr>
<tr>
<td>K6. The relevant regulations concerning treating an animal on an in-patient/out-patient basis, as well as their release criteria, where applicable</td>
<td>S6. Use all relevant laboratory equipment</td>
<td>C6. Take responsibility for handling unsealed radioactive substances in a manner that accidental / unintended exposure of oneself as well as of co-workers is avoided</td>
</tr>
<tr>
<td>K7. The basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)</td>
<td>S7. Be able to work fast and clean when handling radionuclides but not at the expense of incurring an adverse event</td>
<td>C7. Take responsibility for compliance with regulatory requirements and ALARA principles concerning occupational and public radiation exposures, including the risk to pregnant and/or breastfeeding owners/handlers and colleagues</td>
</tr>
<tr>
<td>K8. The way to administer a radionuclide dose in a way that no, or very little, residue is left within the dispensing device (e.g. syringe)</td>
<td>S8. Apply the basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)</td>
<td></td>
</tr>
<tr>
<td>K9. The radiation protection principles, legal requirements and practical solutions which can be used to enhance safe storage, handling and disposal of radioactive materials</td>
<td>S12. Assist the veterinary doctor with the administration of radiopharmaceuticals used for therapeutic procedures</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>K10. State how time, distance, shielding, monitoring and audit can be used to minimize doses received by staff and public</td>
<td>S13. Inform and instruct the owner on the procedures and respond appropriately to questions</td>
<td></td>
</tr>
<tr>
<td>K11. The biological and physical half-lives of the radiopharmaceuticals used for diagnostic and therapeutic procedures</td>
<td>S14. Offer appropriate radiation protection advice to owners/handlers of animals undergoing diagnostic nuclear medicine procedures</td>
<td></td>
</tr>
<tr>
<td>K12. The concepts and tools for scaling administered activity depending on animal size/weight</td>
<td>S15. Explain, where applicable, quantitative dose and risk assessment for members of the public, owners handlers / exposed/potentially exposed as a result of nuclear medicine procedures</td>
<td></td>
</tr>
<tr>
<td>K13. The principles and process steps involved in the administration of the different forms of radiopharmaceuticals applied</td>
<td>S16. Be aware of the fact that after an administration of radioactive substances an animal should be separated from others</td>
<td></td>
</tr>
<tr>
<td>K14. What action should be taken after misadministration and accidental/unintended contamination</td>
<td>S17. Care for animals that require a high level of care whilst at the same time minimizing personal radiation dose</td>
<td></td>
</tr>
<tr>
<td>K15. With good practice in mind, explain how a radioactive spill should be dealt with</td>
<td>S18. Organize clinical workflow so that radioactive animals have minimal contact with at risk individuals (e.g. pregnant females)</td>
<td></td>
</tr>
<tr>
<td>K16. The influence of physiological and pathophysiological processes in the metabolism of radiopharmaceuticals from uptake to elimination</td>
<td>S19. Assess total dose to the owner and/or handler</td>
<td></td>
</tr>
<tr>
<td>K17. The nature and sources of internal and external radiation exposure for workers in nuclear medicine and for members of the public</td>
<td>S20. Identify the required instructions for owners and handlers for minimizing exposure (external and internal)</td>
<td></td>
</tr>
<tr>
<td>K18. Quantitatively assess dose and estimate risk for workers in nuclear</td>
<td>S21. Deal with and/or solve incidents, accidents/events, contamination and notify the person legally responsible for the procedure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S22. Identify procedures that require special operational protection, e.g. extra/appropriate shielding, remote handling or specific dose monitoring, e.g. finger dosimeters or incorporation monitoring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S23. Apply for ethical and legal approval of exposure in medical research, where applicable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C8. Take responsibility for drawing up the correct quantity of radiopharmaceutical for administration, taking into account DRLs where applicable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C9. Take responsibility for the administration of radiopharmaceuticals which are used for diagnostic procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C10. Take responsibility for appropriate radiation protection advice to owners/handlers of animals undergoing diagnostic nuclear medicine procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C11. Assume responsibility for dealing with incidents/accidents/events in a safe and efficient manner</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C12. Contribute to advising owners on the risks and benefits of a planned nuclear medicine procedure</td>
<td></td>
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<tr>
<td></td>
<td>C13. Give instructions to owners/handlers of animals that have been submitted to nuclear medicine therapy procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C14. Assist in explaining procedures to the owner and responding appropriately to their questions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C15. Execute the clinical workflow so that the risk of exposure to individuals (e.g. pregnant females) is minimized</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C16. Take responsibility for providing appropriate care for animals whilst at the same time minimizing personal radiation dose</td>
<td></td>
</tr>
</tbody>
</table>
| | C17. Take responsibility for performing the diagnostic procedure to a suitable
<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K19.</td>
<td>The relevant dose limits for workers (including organ doses), for pregnant workers and for members of the general public, such as owners/handlers.</td>
</tr>
<tr>
<td>K20.</td>
<td>The procedures with potentially high doses for extremities and eye lenses, such as when using high-energy beta emitters.</td>
</tr>
<tr>
<td>K21.</td>
<td>The practical measures that should be carried out to minimize dose to staff, members of the public for hybrid procedures involving X-ray CT.</td>
</tr>
<tr>
<td>S24.</td>
<td>Acquire and process images and data that have clinical relevance, observing the principles of exposure optimization and dose management (e.g. PET/CT) standard, ensuring that no repeat examination is required because of technical deficiency.</td>
</tr>
<tr>
<td>Knowledge (facts, principles, theories, practices)</td>
<td>Skills (cognitive and practical)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>K1. The basic principles underpinning the scientific, effective, safe and efficient use of medical devices used in radiation therapy, including medical imaging devices used for tumour localization and treatment planning and the treatment itself</td>
<td>S1. Use radiation protection methods relating to staff and the general public, taking into account current safety standards, guidelines and regulations</td>
</tr>
<tr>
<td>K2. The principles of radiation protection underpinning radiation therapy treatments and medical imaging examinations for tumour localization and treatment planning to include: radiation hazards, radiation shielding, detection methods, current national and international radiation protection legislation and regulations relating to staff and the general public</td>
<td>S2. Recognize the signs and symptoms associated with treatment in different sites</td>
</tr>
<tr>
<td>K3. The principles of radiobiology underpinning radiation and cytotoxic therapy treatments, and medical imaging examinations for tumour localization and treatment planning to include: cell biology, effects of ionizing and non-ionizing radiation, radiation risks, radio sensitivity, side effects of radiation therapy treatments</td>
<td>S3. Identify the side effects associated with the individual treatment</td>
</tr>
<tr>
<td>K4. The effect of time-dose fractionation, and interaction between cytotoxic therapy and radiation</td>
<td>S4. Define the effects of concomitant treatment</td>
</tr>
<tr>
<td>K5. The principle of Gross Target Volume (GTV), Clinical Target Volume (CTV) and Planning Target Volume (PTV)</td>
<td>S5. Be familiar with reporting systems and reporting protocols</td>
</tr>
<tr>
<td></td>
<td>S6. Describe the radiation hazards and how they are managed</td>
</tr>
<tr>
<td></td>
<td>S7. Effective, safe and efficient use of positioning, immobilization and beam shielding devices used in radiation therapy</td>
</tr>
<tr>
<td></td>
<td>S8. Approach occupational risks to health and safety such as safe moving and handling of the animal and equipment in a safe and effective manner</td>
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</tr>
<tr>
<td>K6.</td>
<td>The principle of Organs at Risk (OAR)</td>
</tr>
<tr>
<td>K7.</td>
<td>The different brachytherapy systems, if applicable</td>
</tr>
<tr>
<td>K8.</td>
<td>The principles of positioning, immobilization and beam shielding devices used in radiation therapy</td>
</tr>
<tr>
<td>K9.</td>
<td>The different radiation therapy verification systems</td>
</tr>
</tbody>
</table>
### TABLE A-8. ADDITIONAL LEARNING OUTCOMES FOR VETERINARY RADIOGRAPHERS AND VETERINARY ASSISTANTS WORKING IN THE FIELD OF INTERVENTIONAL RADIOLOGY

<table>
<thead>
<tr>
<th>Knowledge (facts, principles, theories, practices)</th>
<th>Skills (cognitive and practical)</th>
<th>Competence (responsibility and autonomy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1. The specific requirements of image acquisition and image quality aspects with respect to fluoroscopy</td>
<td>S1. Application of radiation physics to optimize interventional protocols in collaboration with the responsible veterinarian</td>
<td>C1. Assist in the provision of advice to owners/handlers on the radiation-related risks and on the expected benefits of a planned interventional procedure</td>
</tr>
<tr>
<td>K2. The understanding of the following features of fluoroscopes: flat-panel/image-intensifier detectors (including problems with image intensifiers such as geometric distortion, environmental magnetic field effects), continuous and pulsed acquisition (including frame rate), automatic brightness control, high-dose rate fluoroscopy, cine runs, last image hold, road mapping</td>
<td>S2. Application, on a daily basis, of all technical features and capabilities of the available equipment that allow quality-improvement and dose-reduction</td>
<td>C2. Participate in optimizing the technique/protocol used for a given interventional procedure based on animal-specific characteristics and needs</td>
</tr>
<tr>
<td>K3. The radiobiological dose-effect relationships relevant to interventional radiology with respect to staff, public and animal patient safety (such as deterministic effects particularly on the skin and the lens of the eye)</td>
<td>S3. Ability to recognize acute radiation skin effects</td>
<td>C3. Assist in avoiding, where feasible, very high doses to the skin of the animal, which could cause deterministic effects</td>
</tr>
<tr>
<td>K4. The principle of ALARA and its applicability to interventional radiology settings</td>
<td>S4. Application of optimized procedure protocols by using SOPs for interventional radiology and by adapting these to the specific characteristics of the animal</td>
<td>C4. Taking responsibility in avoiding high doses to their skin and eyes</td>
</tr>
<tr>
<td>K5. The meaning of justification and optimization as applied to interventional radiology practices</td>
<td>S5. The use of personal protective equipment by interventional staff, assist in the monitoring of the workplace and individual exposure assessment, investigation</td>
<td>C5. Assist in the procurement of images of sufficient quality for the clinical purpose, while minimizing staff exposure</td>
</tr>
<tr>
<td>K6. The key considerations relevant to radiation protection for an interventional radiology unit</td>
<td>S6. Application of radiation protection measures in interventional radiology, particularly for the hands and the eyes</td>
<td>C6. Work under supervision of the responsible veterinarian in a safe manner when carrying out procedures with ionizing radiation, taking into account current safety standards, guidelines and regulations</td>
</tr>
<tr>
<td>K7. The expected dose-ranges to staff for the main interventional radiology procedures they are assisting in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K8. Their role within the local quality management system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K9. The basic regulatory framework relevant to the practice of veterinary interventional radiology in the country of practice.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| S9. Able to apply the relevant regulations for any clinical situation in IR interventional radiology. |
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