

**Safety Reports Series**

**No. 104**

**Radiation Protection  
and Safety in  
Veterinary Medicine**



**IAEA**

International Atomic Energy Agency

# IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

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RADIATION PROTECTION  
AND SAFETY IN  
VETERINARY MEDICINE

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SAFETY REPORTS SERIES No. 104

RADIATION PROTECTION  
AND SAFETY IN  
VETERINARY MEDICINE

INTERNATIONAL ATOMIC ENERGY AGENCY  
VIENNA, 2021

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Printed by the IAEA in Austria

February 2021

STI/PUB/1894

### IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.

Title: Radiation protection and safety in veterinary medicine / International Atomic Energy Agency.

Description: Vienna : International Atomic Energy Agency, 2021. | Series: IAEA safety reports series, ISSN 1020-6450 ; no. 104 | Includes bibliographical references.

Identifiers: IAEAL 21-01384 | ISBN 978-92-0-107319-8 (paperback : alk. paper) | ISBN 978-92-0-106220-8 (pdf) | ISBN 978-92-0-101221-0 (epub) | ISBN 978-92-0-101321-7 (mobipocket)

Subjects: LCSH: Veterinary radiology. | Radiation — Safety measures. | Veterinary medicine — Diagnosis. | Radiotherapy.

Classification: UDC 614.876:614.9 | STI/PUB/1894

## FOREWORD

Ionizing radiation is used in the practice of veterinary medicine both for diagnosis and for therapy. 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 the radiation exposure of workers and members of the public, and also of animals.

Veterinary practitioners provide a service to animal owners and may be considered to have an obligation to provide veterinary care to the owners' animals. Unlike in human medicine, for which medical practice using radiation is limited to medical facilities, the veterinary use of ionizing radiation can take place outside dedicated veterinary facilities. This poses particular problems and necessitates specific education and training for the veterinary practitioner. In many situations, handling animals in veterinary medicine involves the presence of additional persons, such as animal handlers, in veterinary facilities during procedures for diagnosis and for therapy, and this necessitates additional protective measures.

In the course of developing content on occupational exposure for IAEA Safety Standards Series No. SSG-46, Radiation Protection and Safety in Medical Uses of Ionizing Radiation, jointly sponsored by the International Labour Office, the Pan American Health Organization and the World Health Organization, it became evident that there was also a need for guidance on radiation protection and safety in applications of ionizing radiation in veterinary medicine, covering both occupational exposure and public exposure.

The increasing public demand for best practice animal care will result in advanced imaging equipment being installed in more veterinary medicine facilities, which will require suitably trained personnel with the necessary expertise to carry out procedures safely. This publication provides guidance on the use of ionizing radiation in veterinary medicine in accordance with the requirements established in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. The IAEA officer responsible for this publication was D. Gilley of the Division of Radiation, Transport and Waste Safety.

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# 1. INTRODUCTION

## 1.1. BACKGROUND

IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [1], states the fundamental safety objective and unified set of principles representing a common safety philosophy across all areas of application of the IAEA safety standards. The fundamental safety objective of protecting people — individually and collectively — and the environment from harmful effects of ionizing radiation has to be achieved without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks.

Requirements for achieving this objective and applying the principles and recommendations on meeting these requirements are established in the IAEA safety standards. Relevant requirements are established in particular in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [2].

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. This publication provides guidance on fulfilling the requirements of GSR Part 3 [2] and on following the related recommendations in respect of applications of ionizing radiation in veterinary medicine.

It is assumed in the publication that the State has an effective governmental, legal and regulatory infrastructure for radiation safety that covers the uses of ionizing radiation in veterinary medicine, or else that it is able to develop such an infrastructure. Ionizing radiation is used in the practice of veterinary medicine both for diagnosis and for therapy. 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 also of animals.

Measures for radiation protection and safety are necessary because there is no absolutely safe level of exposure to ionizing radiation. Exposure to ionizing radiation may also pass unnoticed owing to the lack of associated physical sensation and the delay in the onset of some tissue damaging effects.

Veterinary practitioners provide a service to animal owners and may be considered to have an obligation to provide veterinary care to the owners' animals. Unlike in human medicine, for which medical practice using radiation is limited to medical facilities, the veterinary use of ionizing radiation can take place outside of dedicated veterinary facilities. This poses particular problems and necessitates specific education and training for the veterinary practitioner.

In many situations, the handling of animals in veterinary medicine involves the presence of additional persons, such as animal handlers, in veterinary facilities during procedures for diagnosis and therapy, and this necessitates additional protective measures.

Radiation modalities in imaging and therapy will continue to evolve, and practices in veterinary medicine will continue to follow closely the practices that become 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 for long periods. Animal owners will increasingly have access to newer techniques in veterinary medicine, such as computed tomography scans, scintigraphy scans and positron emission tomography scans, as well as radiotherapy treatments. An increasing number of veterinary facilities can be expected to offer these modalities.

Veterinary medicine for companion animals is a service industry, driven largely by animal owners' demand for veterinary diagnostic procedures and treatments. The rise of veterinary medical insurance plays a major part in the advance of veterinary medicine by making advanced diagnostic procedures and treatments more accessible for animal owners.

As advanced imaging equipment is installed in more veterinary facilities, the temptation may arise for veterinary practitioners to offer new modalities and to perform diagnostic procedures more readily, despite questionable veterinary benefits. The lack of available scientific evidence in some cases may complicate the decision making process. Besides the ethical concerns that are associated with this situation, the use of new modalities for the performance of unnecessary or inappropriate diagnostic procedures leads to radiation exposures that could be avoided.

Prevention of disease is considered to be part of human health care. However, pre-purchase radiography of horses, for example, is a case in which ionizing radiation is used with no veterinary indication and for which there is no equivalent in human health care. The purpose of its use is for screening to assess the likelihood of the need for veterinary care of the animal in the future. With the horse's main role having become that of a leisure animal rather than that of a working animal, demand for the practice of radiography for horses will also increase. There are also similar examples of radiographic screening surveys for small animals in the context of breed selection (e.g. to select against hip dysplasia) or the use of thoracic and abdominal radiography for animals for routine check-ups in geriatrics.

Even in States where the use of veterinary medicine has previously remained limited to production animals, the number of companion animals is also now increasing. Some animal owners are seeking the best available veterinary

diagnostic procedures and treatment. As the demand for veterinary medicine increases, the standard of animal care will rise, and this rise will involve the use of more advanced diagnostic and therapeutic techniques. The availability and maintenance of properly serviced equipment and the safe operation of equipment rely on suitably trained persons for all aspects.

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

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

Radiotherapy treatment of animals in many States is likely to be performed in medical (i.e. human) radiotherapy facilities, 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 radiation units may also be used in some States. There is a need for shielding and for radiological procedures to be adapted for megavoltage radiation units, but a benefit of this technique is the few maintenance constraints that exist. However, servicing for these units will probably become less available with time. All aspects of disposal and replacement of the disused radioactive sources used have to be considered.

Newer techniques include intensity modulated radiotherapy, image guided radiotherapy and stereotactic radiosurgery. These techniques are typically associated with machines with higher dose rates and with a large number of monitor units to be delivered per treatment. The use of higher energy machines (>10 MV) will also become 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 replaces a lower energy machine with equipment of higher performance, the existing building will 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 is leading to greater use of advanced equipment for imaging and therapy. Meeting this demand

will necessitate the installation of advanced equipment in more facilities for veterinary medicine. At the same time, there is currently a worldwide shortage of suitably trained persons. The availability of the necessary expertise in selecting, performing and interpreting veterinary imaging studies will need to increase.

## 1.2. OBJECTIVE

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

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

## 1.3. SCOPE

This publication provides information and guidance for ensuring radiation protection and safety<sup>1</sup> 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, procedures in nuclear medicine and radiotherapy.

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<sup>1</sup> 'Protection and safety' is defined in the IAEA Safety Glossary [3] as the protection of people against exposure to ionizing radiation or exposure due to radioactive material and the safety of sources, including the means for achieving this, and the means for preventing accidents and for mitigating the consequences of accidents if they do occur. For the purposes of the IAEA safety standards, protection and safety includes the protection of people against ionizing radiation and safety; it does not include non-radiation-related aspects of safety. Protection and safety is concerned with both radiation risks under normal circumstances and radiation risks as a consequence of incidents, as well as with other possible direct consequences of a loss of control over a radioactive source or any other source of radiation. Safety measures include actions to prevent incidents and arrangements put in place to mitigate their consequences if they were to occur.

The guidance includes measures for the optimization of protection and safety for workers and the public, and measures to optimize the exposure of animals to radiation in veterinary radiological procedures. Radiation in the context of this publication means ionizing radiation. The use of ionizing radiation in veterinary medicine is a planned exposure situation, and Requirements 1–42 of GSR Part 3 [2] apply, as appropriate. The veterinary use of ionizing radiation involves two different categories of exposure. It gives rise to occupational exposure of those workers involved in carrying out radiological procedures and of other workers (e.g. in stables and on farms). It also gives rise to public exposure of members of the public, such as animal owners and other persons assisting with animals, and people in waiting rooms and in animal holding areas.

The publication does not include guidance on the exposure of animals to ionizing radiation for purposes other than diagnosis and treatment. Guidance provided here, describing good practices, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

#### 1.4. STRUCTURE

Section 2 provides general guidance on radiation protection and safety in veterinary medicine. This concerns application of the relevant requirements of the IAEA safety standards for radiation protection, the graded approach, roles and responsibilities, and education and training. Sections 3–5 provide guidance on radiation protection and safety in different areas of use of ionizing radiation in veterinary medicine. Section 3 deals with veterinary diagnostic radiology using X rays. Section 4 covers veterinary medicine using unsealed radioactive sources. Section 5 deals with veterinary radiotherapy. The Annex reproduces the Guidelines on Radiation Protection Education and Training of Veterinary Professionals (commonly known as the HERCA Guidelines) [4], published in 2017 by the Heads of the European Radiological Protection Competent Authorities (HERCA).

Guidance that is common to two or more of these different areas of use of ionizing radiation in veterinary medicine is repeated verbatim, as relevant, in Sections 3–5. This repetition is deliberate for the purpose of ensuring the completeness of each of these three sections.

## **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 radiotherapy. Rapid advances in technology are providing more sophisticated approaches to veterinary imaging and veterinary therapy. Veterinary uses of ionizing radiation take place in a variety of settings, including veterinary facilities and locations outside of veterinary facilities, such as stables and farms.

In veterinary medicine, members of the public, including animal owners and 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 of animals in veterinary medicine, and from their diverse sizes and temperaments.

### **2.2. APPLICATION OF THE REQUIREMENTS FOR RADIATION PROTECTION**

#### **2.2.1. Justification**

The need for justification of exposure to ionizing radiation is common to all types of radiological procedure in veterinary medicine. Paragraph 3.16 of GSR Part 3 [2] requires that:

“The government or the regulatory body, as appropriate, shall ensure that provision...is made for the justification of any type of practice...and for review of the justification, as necessary, and shall ensure that only justified practices are authorized.”

Justification in this context is [2]:

“The process of determining for a planned exposure situation whether a practice is, overall, beneficial; i.e. whether the expected benefits to individuals and to society from introducing or continuing the practice outweigh the harm (including radiation detriment) resulting from the practice.”

No veterinary practice involving exposure to radiation (and indirectly to workers and the public) is to be adopted unless it produces sufficient benefit to the exposed animal to offset the radiation detriment that it causes. A veterinary radiological procedure involving exposure of an animal to ionizing radiation needs to be justified before it can be commenced.

In the justification process for veterinary medicine, occupational exposure, public exposure and exposure of the animal all need to be considered. The radiation detriment arising from the exposure of staff of the veterinary facility and of the public therefore needs to be taken into account. The veterinary surgeon also needs to consider several issues relating to the exposure of the animal in making a decision on justification.

The animal has the legal status of being the property of its owner in almost all States. Owners will request procedures in veterinary medicine to protect their property and to preserve its value. The nature of the relationship between the owner and the animal also needs to be considered. This may be an economic relationship, such as for owners of racehorses or farm animals. Animals are also owned for companionship, such as that offered by cats and dogs, and therefore the value of the animal lies in its significance to the owner. Finally, the veterinary surgeon also needs to consider the welfare of the animal itself. There will be cases where the owner's wishes conflict with the welfare of the animal [5].

### **2.2.2. Optimization of protection and safety**

The optimization of protection and safety<sup>2</sup>, 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<sup>3</sup> factors taken into account. This means that the level of protection would be the best possible under the prevailing circumstances (see Requirements 11 and 21 and paras 1.7, 1.15, 1.17, 3.22–3.25, 3.49, 3.76 and 3.127 of GSR Part 3 [2]).

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<sup>2</sup> 'Protection and safety' is considered to be integrated and needs to be optimized as an integrated whole. 'Optimization of protection and safety' is defined as the process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being as low as reasonably achievable, economic and social factors being taken into account (the ALARA principle) [3]. 'Optimization of protection and safety has been implemented' means that optimization of protection and safety has been applied and the results of that process have been implemented [3].

<sup>3</sup> 'The environment' is defined as the conditions under which people, animals and plants live or develop and which sustain all life and development; especially such conditions as affected by human activities [3].

Dose constraints are used at the planning stage for the optimization of protection and safety and are applicable for both occupational exposure and 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 (see paras 1.22, 1.23, 1.25, 1.26, 1.28 and 3.25 of GSR Part 3 [2]).

Depending on the situation, the constraint can be expressed as a single dose or as a dose over a given period of time. Since veterinary staff often perform various 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 exceedance 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 ('as low as reasonably achievable') are time, distance and shielding. These three factors need to be combined in the design of buildings and rooms for veterinary facilities, in the design of radiological equipment, and in local rules and procedures. The combination of these three factors permits the optimization of radiation protection for occupational exposures and public exposures.

Occupational exposure and public exposure can be reduced by one or more of the following means<sup>4</sup>:

- (a) Minimizing the exposure time of the worker or the member of the public to the source (decreased exposure time, decreased exposure);
- (b) Maximizing the distance between the worker or the member of the public and the source (increased distance, decreased exposure);
- (c) Using appropriate shielding between the radiological equipment and the workers and members of the public (increased shielding, decreased exposure).

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<sup>4</sup> The exposure of workers and members of the public can be further reduced by using standard operating procedures and by using positioning devices and animal restraints, such as sedation or general anaesthesia and mechanical restraints or manual restraint (see Sections 3–5 for further guidance).

### 2.2.3. Dose limits

The requirements for dose limits<sup>5</sup> are that dose limits be applied for occupational exposure and public exposure of individuals in planned operations. Dose limits for workers and dose limits for members of the public are established in GSR Part 3 [2] (see Requirements 12 and 21, paras 1.7, 1.17, 2.11, 3.26–3.28, 3.76 and Schedule III) and are presented in Table 1.

GSR Part 3 [2] takes into account the latest available recommendations of the International Commission on Radiological Protection [6]. Although the dose limits in Table 1 are maximum permitted values, all doses are to be kept as low as reasonably achievable [2].

TABLE 1. DOSE LIMITS (*see Schedule III of GSR Part 3 [2]*)

	Occupational		
	Workers	Apprentices and students (16–18 years)	Public
Effective dose	20 mSv per year averaged over five consecutive years, 50 mSv in any single year	6 mSv in a year	1 mSv in a year
Annual equivalent dose in			
Skin	500 mSv	150 mSv in a year	50 mSv in a year
Hands and feet	500 mSv	150 mSv in a year	—
Lens of the eye	20 mSv per year averaged over five consecutive years, 50 mSv in any single year	20 mSv in a year	15 mSv in a year

<sup>5</sup> The ‘dose limit’ is defined as the value of the effective dose or the equivalent dose to individuals in planned exposure situations that is not to be exceeded [3].

### 2.3. USE OF THE GRADED APPROACH

The ‘graded approach’<sup>6</sup> is a concept that underpins the application of the system for protection and safety. Paragraph 2.12 of GSR Part 3 [2] 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.” GSR Part 3 [2] places responsibilities in respect of a graded approach on each of the following: 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 with 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 with a single conventional X ray unit would be required to have a quality assurance programme. However, it would not need to be as comprehensive a quality assurance programme as that needed for a veterinary practice with a radiation therapy facility.

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

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<sup>6</sup> The ‘graded approach’ is, for a system of control, such as a regulatory system or a safety system, defined as a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control [3].

## 2.4. ROLES AND RESPONSIBILITIES

### 2.4.1. Government

#### 2.4.1.1. General

Requirements for the roles and responsibilities of governments in respect of radiation protection and safety are established in GSR Part 3 [2] (see Requirement 2 and paras 1.7–1.11 and 2.13–2.28) with further requirements established in IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety [7]. These responsibilities for radiation protection and safety include, but are not limited to:

- (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 in radiation protection in veterinary practices, 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;
  - Radioactive waste management strategy.

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 persons with the appropriate competences are allowed to assume specific roles and responsibilities. For the veterinary use of ionizing radiation, this applies in particular to persons 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 associations for technical standards, 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 veterinary medicine. In States with organizations such as these, the government or regulatory body is encouraged to foster cooperation between all bodies that can contribute to radiation protection. In States without such organizations, it is advisable that the government or regulatory body considers adopting or adapting relevant policies from organizations in other States.

#### **2.4.2. Regulatory body**

The regulatory body<sup>7</sup> for radiation protection is required to fulfil regulatory functions such as: setting regulatory requirements and guidelines; reviewing and assessment of applications for authorization; authorizing and inspecting facilities and activities; and enforcement of legislative and regulatory provisions (see Requirements 3, 19 and 29 and paras 1.7–1.11, 2.15–2.20 and 2.29–2.38 of GSR Part 3 [2]).

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, using a graded approach, determine the form of authorization needed — specifically registration or licensing. Registration is advisable for facilities that perform diagnostic imaging but that do not perform interventional procedures. Licensing is advisable 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 operating organization of a 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 of the different parties in radiation protection and involved in radiological procedures. These include the veterinary surgeon, the veterinary assistant, the radiation protection officer and the qualified expert.

It is advisable for the regulatory body to recognize the qualifications of key persons in radiation protection in veterinary medicine, such as the veterinary

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<sup>7</sup> The 'regulatory body' is defined as an authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating the nuclear, radiation, radioactive waste and transport safety [3].

surgeon and the qualified expert in radiation protection. For this purpose, the regulatory body usually establishes 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 an authorization. The duration of the authorization is decided in accordance with regulations based on with the complexity of the procedures performed. This authorization can be withdrawn when needed. 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 veterinary surgeon 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 good practice for the regulatory body to provide licensees with clear acceptance criteria for all types of veterinary equipment, including the minimum frequency of retesting the equipment. This ensures that the equipment used is considered safe for the people involved and also for the animals. Acceptance criteria and a minimum frequency of retesting the equipment are especially necessary in the case of second hand equipment to ensure that it is fit for purpose for its intended use with animals (see Section 3.2.2.1).

The regulatory body can also choose to establish the methodology for establishing 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 take care of an animal that has been injected with radioisotopes.

In the case of incidents or other unusual events, such as the loss of a source or the exceedance of a dose limit, it is advisable that the regulatory body be informed. The need for notification of such incidents, and the practical requirements for such a notification, can be established by the regulatory body. The regulatory body may communicate these to veterinary facilities in the form of the provision of expertise in order to avoid other 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 on registrants and licensees for ensuring radiation protection and

safety in a veterinary radiation facility are established in GSR Part 3 [2] (see Requirements 9, 21 and 23–28 and paras 3.13–3.15).

Almost all the requirements that apply in the veterinary use of ionizing radiation, in particular the requirements for occupational radiation protection, place responsibilities on the registrant or licensee as well as on the employer. However, the veterinary use of ionizing radiation usually involves a multidisciplinary team led by a veterinary surgeon 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 veterinary surgeon responsible for the particular radiological procedure, as described in the management system and signed off by those who assume any responsibility. 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*

Application of the requirements for radiation protection and safety of GSR Part 3 [2] to the use of radiation in veterinary medicine needs to be complementary to and consistent with the application of the set of requirements that ensure good veterinary practice. The management of the veterinary radiation facility needs to ensure complementarity between the requirements for radiation protection and safety and requirements for the delivery of animal care in the veterinary facility. This complementarity can be achieved by means of an appropriate management structure and by the use of a management system.

With regard to the management for protection and safety, Requirement 5 of GSR Part 3 [2] states that **“The principal parties shall ensure that protection and safety are effectively integrated into the overall management system of the organizations for which they are responsible.”** In the context of this publication, this requirement applies to the registrant or licensee of the veterinary facility.

Paragraphs 2.47–2.52 of GSR Part 3 [2] establish additional requirements: on demonstrating commitment to protection and safety at the highest levels within the organizations concerned; on promoting and maintaining safety culture; and on taking into account human factors and supporting good performance and good practices to prevent human and organizational failures.

Further requirements for facilities and activities in general are established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [8], and related recommendations are provided in IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Facilities and Activities [9]. Application of the requirements and the development of a

management system are subject to 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 the management system and for quality management will not be discussed further in this publication. It is emphasized, however, that effective management for protection and safety depends on commitment at the highest level of management of the veterinary facility. This commitment includes the provision of all the necessary resources. The following guidance is limited to those elements of the management system relating to protection and safety.

Requirement 4 and paras 2.42 and 2.43 of GSR Part 3 [2] establish requirements for a protection and safety programme in general. Requirement 5 and para. 2.48(b) establish requirements for a description of the planned and systematic actions necessary to provide adequate confidence that the requirements for protection and safety are fulfilled (i.e. requirements for a quality assurance programme). Requirements are also established for a radiation protection programme for occupational exposure in Requirement 24.

All three of these programmes would be part of the overall management system of the veterinary facility<sup>8</sup>. Detailed guidance on the radiation protection programme for occupational exposure and on the quality assurance programme is given in Sections 3–5.

The 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 identified from experience. Safety culture includes individual and collective commitment to safety on the part of the leadership, the management and personnel at all levels (see para. 1.12 of GSR Part 3 [2]).

The concept of safety culture has been a vital element in discussions about safety in many industries. This reflects the recognition that, while engineered controls are essential for controlling risks, it is equally important to obtain the commitment of the workforce to treat safety as a priority. The commitment of the workforce is obtained through 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 [10–12] and in human health care [13, 14]. There has also been a report published on an initial study to measure safety culture in veterinary practices [15].

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<sup>8</sup> The veterinary facility may be a stand-alone entity, or it may be part of a larger organization, such as 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 promote continuous improvement. This implies a commitment by staff to strive for continuous improvement in veterinary uses of ionizing radiation. Feedback from operational experience and feedback from lessons identified following accidental exposures or following incidents such as near misses need to be applied systematically, as part of the process of continuous improvement. The management system needs to provide for record keeping and for access to records (see Sections 3–5 for details).

#### *2.4.3.2. Radiation protection officer*

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

For a veterinary radiation facility, the radiation protection officer oversees the application of radiation protection requirements for occupational exposure and public exposure. The radiation protection officer may also provide the registrant or licensee with general advice on radiation protection. The radiation protection officer could be a veterinary surgeon or someone 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 technologies used and on the practice of the veterinary radiation facility. In some facilities, several radiation protection officers may be designated.

#### *2.4.3.3. Veterinary surgeon*

Veterinary surgeons work independently to perform or oversee diagnostic or therapeutic procedures in animals. In veterinary applications, such procedures are performed only by a veterinary surgeon who is properly trained and is registered, accredited or certified for such work [16]. It is advisable that before performing such procedures, veterinary surgeons be formally recognized by the regulatory body as qualified for work using ionizing radiation.

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

For veterinary radiological procedures, the referring veterinary surgeon is usually responsible for conducting the veterinary examination that indicates the veterinary radiological procedures to be performed. The referring veterinary surgeon is the veterinary surgeon who initiates the request for a veterinary radiological procedure (see Section 2.4.4). It is advisable that the veterinary surgeon or other operator who carries out the radiological procedure consult

the referring veterinary surgeon in determining the radiological procedure to be performed and planning the exposure for the animal.

The operator<sup>9</sup> then performs the procedure and informs others of the possible risks and of any assistance necessary during the procedure. Usually, the operator is a veterinary surgeon. The operator has the responsibility for informing the animal owner and all staff and animal handlers involved in the procedure of the possible risks associated with radiation exposure during the procedure (see Figs 1 and 2).



*FIG. 1. A set-up 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 to an eye hook attached to the wall. 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 of Royal Veterinary College, London.)*

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<sup>9</sup> ‘Operating personnel’ is the individual workers engaged in the operation of an authorized facility or the conduct of an authorized activity [3]. This may be shortened to operator(s), provided that there is no danger of confusion with ‘operator’ in the sense of ‘operating organization’. In the context of this publication, operators will usually be veterinary surgeons. In some States, veterinary technologists are allowed to be operators and to perform some procedures.



*FIG. 2. A set-up for a radiotherapy procedure for a dog under general anaesthesia. The operator is responsible for positioning 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 of Vetotech, Villeneuve d'Ascq.)*

#### *2.4.3.4. Veterinary technologist and nurses*

Veterinary technologists and nurses can participate in procedures using ionizing radiation. They need to have appropriate education, training, qualification and competence 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 veterinary surgeon. In some States, 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 regard are required to be formally recognized by the regulatory body or other relevant authority (see para. 2.21(b) of GSR Part 3 [2]).

#### 2.4.3.6. Other persons assisting with veterinary radiological procedures

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

In many situations, the need for animal handling necessitates the presence of additional persons in the room, or in the stables or on the farm, during radiological procedures. This may necessitate additional protective measures (see Fig. 3). Such additional persons 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 take care of the animal upon its release.



*FIG. 3. For some X ray imaging procedures, several persons 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 veterinary surgeon) 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 the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent.)*

#### **2.4.4. Referring veterinary surgeon**

The referring veterinary surgeon is the veterinary surgeon who initiates the request for a radiological procedure. A referral can be considered to be a ‘request for a professional consultation or opinion’ rather than an ‘instruction or order to perform’. For veterinary radiological procedures, the referring veterinary surgeon is usually responsible for conducting the veterinary examination that indicates the veterinary radiological procedure(s) to be performed. For this reason, it is advisable on referral that the referring veterinary surgeon provides any relevant information on the veterinary context and on the veterinary history of the animal for consideration by the veterinary surgeon offering the radiological procedure, for an informed decision making process.

#### **2.4.5. Manufacturers and other suppliers**

Manufacturers and other suppliers of radiological equipment and software, and of radioactive sources — both sealed and unsealed sources — can influence the delivery of radiation. Such manufacturers and other suppliers thus have responsibilities in relation to the design, manufacture and performance of the radiological equipment and software, and of the radioactive sources, as well as the operating instructions for their safe use (see para. 1.8 of GSR Part 3 [2]). Relevant requirements are established in para. 3.49 of GSR Part 3 [2]:

“Registrants and licensees who are manufacturers or other suppliers of radiation generators and radioactive sources shall ensure that the following responsibilities are discharged, as applicable:

- (a) Supplying a well designed, well manufactured and well constructed radiation generator or radioactive source and device in which the radiation generator or radioactive source is used that:
  - (i) Provides for protection and safety in accordance with the requirements of [GSR Part 3];
  - (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 the 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 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 shielding and by other protective devices is optimized.”

Suppliers and manufacturers of radiation generators and radioactive materials are required to be authorized. Veterinary facilities for which radiation generators and radioactive materials are purchased are also required to be authorized (usually by means of a licence) for their intended use (see Requirement 7 and paras 3.5, 3.8, 3.9 and 3.55(c) of GSR Part 3 [2]).

Appropriate measures are required to be taken for the transport of radioactive material, including the transport of equipment containing radioactive material [17] and for security [18] (see para. 3.53 of GSR Part 3 [2]).

Suppliers and manufacturers need to provide specific advice and training on the correct operation of their equipment and materials if so requested by registrants or licensees (see paras 2.44 and 3.76(b) of GSR Part 3 [2]).

#### **2.4.6. Maintenance and service engineers**

The 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 or the vendor) or by the veterinary facility itself (e.g. as part of an engineering or a veterinary engineering department or a service department). If 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 needs to follow the rules for radiation protection, for general health and safety, and procedures established by the employer, as well as local 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 in the performance of radiological procedures that include diagnostic examinations, interventional procedures and therapeutic procedures (treatments). In each case, measures for radiation protection and safety for the occupational exposure and

public exposure that are associated with the radiological procedure depend strongly on the skills and expertise of the veterinary surgeons involved.

The education, training, qualification and competence of the relevant professional staff are therefore essential for 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 [2] also establishes requirements on the government to be responsible for ensuring that requirements for education, training, qualification and competence are established, and to be responsible for ensuring that arrangements are in place for 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 would be useful in this regard. Furthermore, the regulatory body will need to verify the application of the requirements for education, training, qualification and competence in radiation protection, both 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 needs to have the responsibility for ensuring that all the veterinary surgeons in that facility with responsibilities for protection and safety have the appropriate education, training, qualification and competence. The level of qualified training in radiation protection for practitioners in the veterinary profession may vary between regions. The promotion of training and certification in radiation protection for veterinary surgeons and veterinary technologists is desirable.

There is a major part to be played in such promotion by veterinary schools, companies for continual professional development and national veterinary boards, as well as international speciality colleges in radiology and radiotherapy. Qualified experts in radiology and radiotherapy and radiation protection officers may also be directly involved in training other veterinary professionals.

Paragraph 3.110 of GSR Part 3 [2] requires employers, in cooperation with registrants and licensees, to provide staff with, 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 for all staff as part of their continual professional development. Specific instruction and training of staff for protection and safety are also to be provided when new radiological procedures, equipment, software and technologies are introduced in veterinary facilities.

The objectives of the specific instruction and training of staff for protection and safety include imparting knowledge of health risks associated with their occupational exposure and means of risk reduction. The objectives also include providing training in the operation of specific equipment and training for performing specific procedures. Training in the operation and emergency

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

In addition to acquiring knowledge, skills and competences relating to radiation protection and safety, persons involved in veterinary imaging procedures also have to be competent in handling animals. They need to be aware that animals in pain, in unfamiliar surroundings or under sedation may behave differently than they do in normal circumstances. The persons concerned need to understand the hazards involved in working with animals and they need to be confident that they can perform their assigned duties.

An example of the necessary knowledge, competences and skills for veterinary surgeons and veterinary assistants are those developed by HERCA and described in detail in the HERCA Guidelines [4] (see the Annex). Further guidance on education, information, instruction 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, typically in fields, stables or barns. The procedure is often performed with the help of members of the public. These situations necessitate special considerations for radiation protection.

Interventional radiography and computed tomography are performed in veterinary facilities by workers who are subject to occupational exposure. This section provides general advice applicable to all the above mentioned procedures and discusses specific needs where applicable.

Persons 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 the 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 may also include work on farms and work with zoo animals, suitable temporary areas for radiography need 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, stables and operating theatres.

#### 3.2.1.1. *Fixed facilities: Design of X ray rooms*

The three factors relevant to dose reduction ('as low as reasonably achievable') 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 entire room is usually specified as a controlled area.

In many veterinary practices, imaging rooms may be multipurpose 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 be dedicated to radiography. However, when radiography is in process, the room may only be used simultaneously for any other purpose 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 facility needs to be considered. Account needs to be taken of both safety related aspects and practical considerations. The practical considerations include the 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 a power supply need to be discussed with the equipment providers 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 needs 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 an animal being imaged is uncooperative. Larger rooms also permit the use of mechanical restraints such as stocks for the horse, which increase general safety.

The design of a fixed facility needs to include consideration of an air-conditioning system sufficient to maintain the temperature and humidity in examination rooms, as well as in areas with computer equipment and imaging detectors. The temperature and humidity need to be maintained within the range specified by the manufacturers of the equipment. They also need to be consistent with any requirements for the control of temperature and humidity for human occupancy for purposes of health and safety. The design is part of the application and any changes in the design would need to be approved by the regulatory body depending on the regulator requirements.

Firefighting equipment needs to be kept available in all areas.

### *3.2.1.2. Considerations relating to shielding*

Shielding includes structural and ancillary protective barriers that are best considered at the design stage of the facility and that 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.

There may be requirements in some States for designs for shielding and reviews of plans for shielding to be submitted to the regulatory body for review 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 have been made.

For radiography, all possible intended directions of the X ray beam need to be taken into consideration in the design of the room. This is so that the X ray beam cannot be directed at any area that 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 most applications in practice with horses a horizontal beam is used.

Walls, floors, doors and 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, thereby reducing the need for repeat exposures, and better collimation, thereby reducing the scattering of radiation.



*FIG. 4. Use of a protective barrier (shielding screens) placed at the control console to reduce exposure of the operator when performing X ray examinations. (Courtesy of the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent.)*

#### 3.2.1.4. *Warning signs*

Signs and warning lights, conspicuously positioned, need to be placed 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 [19]. 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 veterinary surgeon 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 will preferably 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 procedures are also performed within veterinary facilities but outside controlled areas when using mobile units or portable units in rooms or in operating theatres. In all 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 has the same considerations as the establishment of a designated X ray room: the distance and the direction of the X ray beam have 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 a 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, software and ancillary equipment**

#### *3.2.2.1. Purchase of equipment*

Registrants and licensees are required to take responsibility for the radiation safety of the radiological equipment to be used in veterinary radiation facilities (see paras 2.40, 3.38 and 3.42 of GSR Part 3 [2]). Registrants and licensees therefore need to set specifications for the purchase of new radiological equipment.

X ray generators and receptors need to be compatible with their intended use. For example, many of the proximal areas of a 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 in a standing position, 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 ensure that it meets the relevant technical standards of the International Electrotechnical Commission and the International Organization for Standardization, or equivalent national standards. The International Electrotechnical Commission has issued international technical standards applicable to medical radiological equipment. The International Organization for Standardization also publishes international technical standards applicable to medical radiological equipment.<sup>10</sup>

In some States, veterinary surgeons may need to consult an 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. It needs to be ensured that second hand equipment is considered safe for the people involved and also for the animals, and that it is

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<sup>10</sup> Up to date lists of the current standards are available at [www.iec.ch](http://www.iec.ch) and [www.iso.org](http://www.iso.org)

fit for its intended use with animals (see Section 2.4.2). 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 guidance on the design features of medical radiological equipment are provided in IAEA Safety Standards Series No. SSG-46, Radiation Protection and Safety in Medical Uses of Ionizing Radiation [20].

#### 3.2.2.2. *Maintenance of equipment*

GSR Part 3 [2] establishes requirements for the 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 proper functioning of equipment is essential to the efficacy of diagnostic procedures. Maintenance and servicing of radiological equipment need to be included in the quality assurance programme. Maintenance and servicing are usually performed by appropriately authorized engineers or technicians who understand the specifications of veterinary radiological equipment.

The registrant or licensee needs to establish the necessary arrangements for maintenance with the manufacturer's representative when purchasing the equipment. Maintenance and servicing 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 need to be carried out at intervals recommended by the manufacturer or by the regulatory body. While equipment is under servicing, it is not to be used until the service has been completed, tested and proper functioning is verified.

Maintenance programmes for radiological equipment need to cover the veterinary radiological equipment and its hardware and software components, including networks, databases, viewing monitors, view boxes and other software systems supporting the hardware in the veterinary facility (e.g. picture archiving and communication systems, radiology information systems).

In addition to ensuring the safety of the X ray generating parts of the radiological equipment, ensuring the safety of the electrical and mechanical parts of the radiological equipment is an important part of the maintenance programme. The safety of the electrical and mechanical parts of the radiological

equipment can have direct or indirect effects on radiation safety. These parts need to be included in the maintenance protocol.

The engineer or technician carrying out maintenance and servicing needs to follow the rules for radiation protection, rules for general health and safety, and the procedures established by the employer, as well as the rules and procedures of the veterinary radiation facility. Records of completed maintenance (both 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. These reports are to be archived as part of the quality assurance programme.

#### 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 a veterinary exposure has 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 the relevant international 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 [21–23].

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 needs to be not 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. The colour of the 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 [22, 23].

#### 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 need 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 I.

### 3.2.2.5. *Positioning aids*

Mechanical restraints and positioning equipment can facilitate imaging procedures. They can also reduce the need for having additional persons in the imaging area for the manual restraint of animals.

Adequate sedation of animals can minimize risks as well as minimizing radiation exposure. For appropriate choices of means of sedation, the necessary depth and duration of sedation 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 contraindicated (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).

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 a horse that has been sedated 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 person holding the

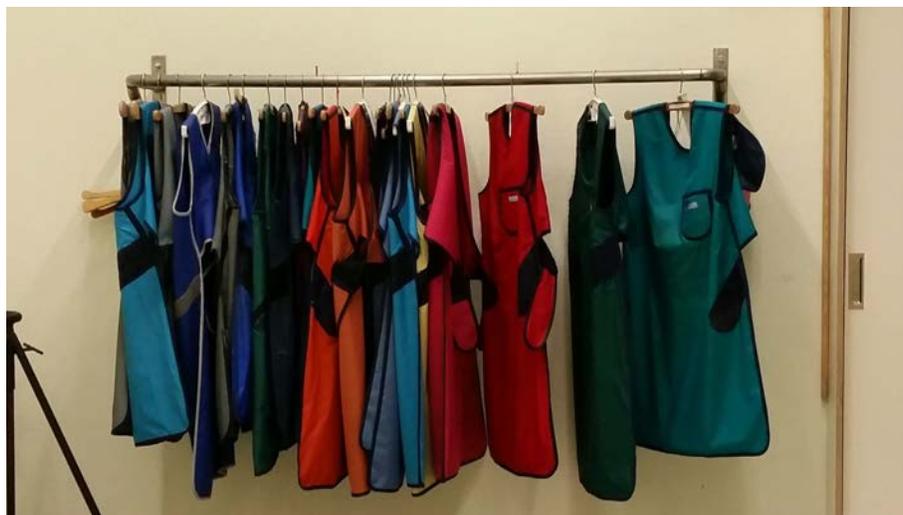


FIG. 5. Storage of lead aprons. (Courtesy of North Carolina State University, Raleigh.)



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 of the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, University of Ghent.)



FIG. 7. A set-up 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 of Royal Veterinary College, London.)



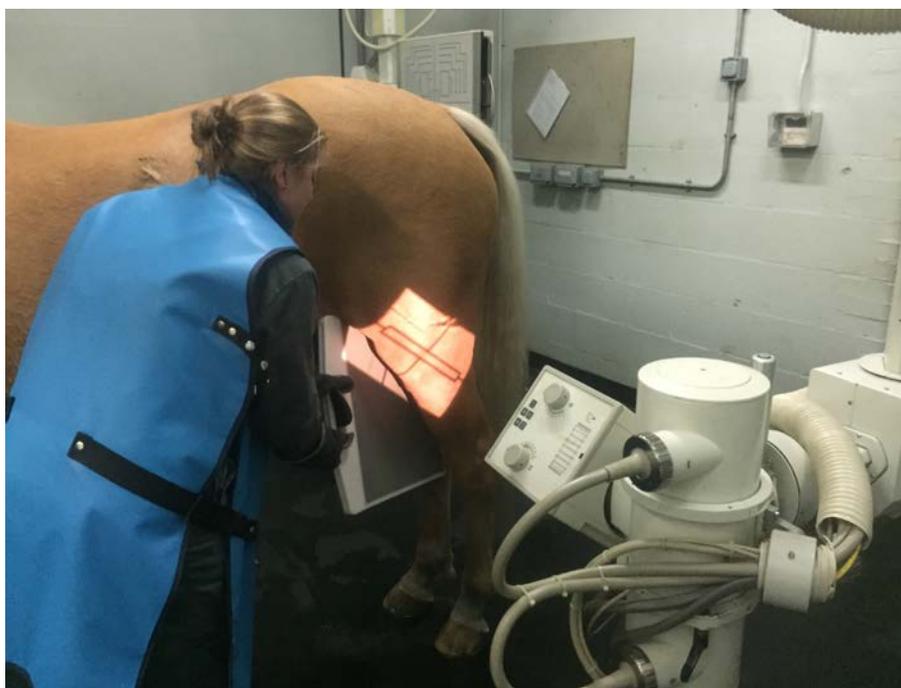
*FIG. 8. A standing horse positioned for a computed tomographic examination of the head. The head is stabilized in the computed tomography gantry with a plastic cradle commonly used for the imaging of babies in hospitals. The horse has a rope halter to avoid the metal artefacts associated with the buckles 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 of Royal Veterinary College, London.)*



*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 of Royal Veterinary College, London.)*

plate to maximize his or her distance from the radiation source. For radiography of the spine and thorax, plate holder stands are advisable; they eliminate the need for a person to be holding the plate during the high exposures necessary for these areas.

The physical safety of the persons 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 horse, the use of a plate holder increases the likelihood of an alarmed reaction by the horse. Holding the plate by hand in a lead glove while collimating the beam is considered to be the safer option (see Fig. 10).



*FIG. 10. A lateromedial radiograph of the stifle joint using a high output ceiling mounted generator and a digital plate. Since the stifle joint (rear leg) is very close to the area to be imaged, the plate needs to be pushed as far as possible proximally and caudally. This is usually best achieved by holding the plate by hand. Care needs to be taken to collimate the image as tightly as possible to avoid exposure of the person holding the plate. (Courtesy of Royal Veterinary College, London.)*

#### 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, 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

#### 3.3.1. **General**

In veterinary diagnostic radiology, workers subject to exposure are usually veterinary surgeons and those veterinary technologists who are permitted under national regulations to perform radiography. The general approach is to classify work areas and then to determine who needs access to these areas and are classified as occupationally exposed.

Workers in veterinary diagnostic radiology who are subject to exposure to radiation from sources that are not required by or directly related to their work are required to be afforded the same level of protection against exposure as members of the public (see para. 3.78 of GSR Part 3 [2]). Such workers include other veterinary professionals such as nurses, cleaners, administrative personnel, and other service staff and support staff, and some animal handlers and other staff employed by the veterinary facility who may need to assist with animals during a radiological procedure. Information needs to be provided to such workers on relevant safety related aspects and on local rules and procedures.

It is therefore required 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.

Section 3 provides guidance on radiation protection specific to veterinary diagnostic radiology. More general and comprehensive recommendations and guidance on occupational radiation protection that are applicable to all areas of use of radiation (including non-veterinary and non-medical uses) are provided in IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection [24], which includes recommendations and guidance on radiation protection programmes, on assessment of occupational exposure and on providers of dosimetry services.

GSR Part 3 [2] 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 engineered controls, followed by administrative controls and, as a last level, personal protective equipment (see Requirement 24 and para. 3.93). Shielding is a type of engineered control, and structural shielding is preferred over ancillary shielding.

To this end, and as required in GSR Part 3 [2], written local rules and procedures are to be established for a veterinary radiation facility. The purpose of the local rules and procedures is to ensure protection and safety for operators and other persons (see Requirement 24 and paras 3.90(d) and 3.94).

The local rules need to include measures for the optimization of protection and safety for occupational exposure, both in normal work and in abnormal conditions. Local rules and procedures also need to cover the wearing, handling and storage of personal dosimeters, and specify investigation levels<sup>11</sup> and follow-up actions. 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. imaging rooms). It is advisable to develop standard operating procedures for each procedure in veterinary diagnostic radiology and to make periodic reviews.

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

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

- (a) Designing radiation facilities and equipment for best practice in procedures, especially procedures in the use of ancillary devices;
- (b) Correctly selecting imaging procedures on the basis of sound veterinary practice;
- (c) 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.

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<sup>11</sup> An ‘investigation level’ is defined as the value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation would be conducted [3].

### **3.3.2. Arrangements under the radiation protection programme**

#### *3.3.2.1. Classification of areas*

Various areas and rooms in a veterinary radiation facility are required to be designated and classified as controlled areas or supervised areas, in accordance with Requirement 24 and paras 3.88–3.92 of GSR Part 3 [2]. Once designated, these areas are subject to the requirements established in paras 3.89 and 3.90 (for controlled areas) and paras 3.91 and 3.92 (for supervised areas). These include requirements for:

- 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;
- Provision of facilities for personal decontamination.

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.

The following provides 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 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 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. To this end, and as required in GSR Part 3 [2], written local rules and procedures are to be established for a veterinary nuclear medicine facility. The purpose of the local rules and procedures is to ensure protection and safety for operators and other persons (see Requirement 24 and paras 3.90(d) and 3.94). 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.

Based on a 2009 survey of occupational health hazards in veterinary medicine, Epp and Waldner [25] find that all veterinary surgeons 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 veterinary surgeons who manually restrained animals during radiography reported accidental exposure to X rays [25]. 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 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 opting 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 such 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-ionizing imaging modalities if the veterinary benefit is expected to be the same. Evidence based veterinary medicine, including the correct application of imaging procedures, necessitates having current knowledge and veterinary reasoning skills: it is the veterinary surgeon's responsibility to pursue continual professional development.

Movement of the animal needs to be kept to a minimum by using adequate restraints to minimize the exposure of workers and of the animal itself. Where possible, the animal can be adequately restrained by means of sedation or general anaesthesia and mechanical restraints (see Section 3.2.2.5). In some situations, it is not possible to restrain the animal by means of sedation, general anaesthesia or mechanical restraints, and animal handlers have to restrain the animal manually by holding it during the procedure. The safety of workers at risk of injury by the 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. Nevertheless, 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's owner) may be involved in imaging procedures (see Fig. 3, Section 2.4.3.6). The operator needs to collimate the beam to the area of interest for diagnosis on the animal so as 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. Therefore, the operator also needs to inform the animal handler 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. They need to give their informed consent to participation in the procedure. 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 an improperly carried out 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 of Vetotech, Villeneuve d'Ascq.)*



*FIG. 12. A second example of an improperly carried out 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 of Vetotech, Villeneuve d'Ascq.)*

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 and thereby 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 for previous systems. A record of the exposure values, the number of exposures, the area, the date and the identification of the animal can be kept either digitally or on paper.

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 include the following:

- (a) Persons involved in the procedure are to be as far away as possible from the primary beam and from the animal to be exposed, to minimize their exposure to scattered radiation; no body part of the person is to be in the primary beam.
- (b) Plate holders on extensions or with handles are to be used, allowing the person holding the plate to be positioned away from the beam.
- (c) Persons within controlled areas are to wear protective clothing, including lead aprons, thyroid shields, lead gloves and lead glasses, as applicable.
- (d) Portable and mobile X ray devices are to be mounted on a stand and not hand-held; exceptions will depend on applicable local regulations.
- (e) 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 startled reaction of the animal).
- (f) The X ray beam is to be directed away from people and doors.
- (g) Verbal warnings are to be given of an imminent exposure to alert other persons.
- (h) Workers who are 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.
- (i) Members of the public who are pregnant are not to hold animals or to assist during procedures.
- (j) 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) is to be operated or used 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 regard. Additional procedures need to be developed specifically for the use of imaging in the facility, to provide easy access to readily understandable information on the functioning of the equipment. The final documented set of operational procedures is to be approved by the licensee of the veterinary radiation facility and incorporated into the facility's quality management system.

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. They also need to be given adequate training in what to do when things go wrong. Refresher training needs to

be given at appropriate intervals. Additional training needs to be provided when new radiological equipment is installed in the facility or new techniques are introduced.

### *3.3.2.3. Monitoring of the workplace*

Requirement 24 and paras 3.90 and 3.96–3.98 of GSR Part 3 [2] set out the requirements and responsibilities for monitoring of the workplace. Monitoring of the workplace for radiation levels is necessary to ensure protection and safety, and it is used to minimize exposure of workers. Workplace monitoring needs to be performed and records need to be maintained as part of the veterinary nuclear medicine facility's radiation protection programme (see paras 3.96–3.101).

Workplace monitoring comprises the taking of measurements in the working environment and interpretation of the results, assessment, investigation and reporting. 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 especially important for staff members who do not have individual monitoring. General recommendations and guidance on workplace monitoring are given in GSG-7 [24]. Workplace monitoring can lead to corrective measures being recommended, if necessary.

The veterinary radiation 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 after 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**

#### *3.3.3.1. Individual monitoring for assessment of occupational exposure*

Paragraph 3.99–3.102 of GSR Part 3 [2] require 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 who may receive a significant dose from occupational

exposure. The dose limits of GSR Part 3 [2] for occupational exposure and for public exposure are presented in Table 1, Section 2.2.3.

Individual monitoring provides information about radiation exposures of workers for a record of work practices and to meet regulatory requirements. 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, radio-photoluminescence 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 persons 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 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 person in that veterinary facility.

Personal dosimeters are worn for specific monitoring periods that are specified by the regulatory body in most States. The monitoring period (i.e. period of use of a dosimeter) is typically in the range of one to three months. The monitoring period is determined by such factors as availability for service, workload and type of work.

A one month monitoring period is typically used for personnel 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 for most persons 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, reading and reporting of doses recorded on dosimeters are to be avoided. Dosimeters need to be sent from the veterinary radiation 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 not in use, personal dosimeters need to be kept in a dedicated place. They need to be protected from damage and from irradiation. If a person loses his or her personal dosimeter, the person needs to inform the radiation protection officer. The radiation protection officer needs to perform a dose assessment, record this evaluation of the dose and add it to the person'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 a person's dose is to use his or her recent dose history. In cases where the person performs non-routine types of work, it may be better to use the doses of co-workers having similar exposure conditions as the basis for the dose estimate.

### *3.3.3.2. Investigation levels for workers*

Investigation levels are different from dose constraints and dose limits. 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 need to be carried out and corrective actions need to be taken when the dose received by a worker exceeds an investigation level.

The following are examples of investigation levels for workers in veterinary radiation facilities: pro rata 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 [26] 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 [26, 27].

Abnormal conditions or unusual events also necessitate 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. Recommendations and guidance on investigation levels are provided in GSG-7 [24].

An investigation needs to be initiated as soon as possible following the exceedance of an investigation level or abnormal conditions or an incident (see paras 1.31, 3.45–3.48 and 3.94 of GSR Part 3 [2]). A written report needs to be prepared concerning: the cause; the determination and 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 as described in regulations.

#### *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 (see paras 3.103–3.107 of GSR Part 3 [2]).

As well as for demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary radiation 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. Paragraph 3.106(a) of GSR Part 3 [2] requires employers to provide workers with access to records of their own occupational exposure. Further general recommendations and guidance on records of occupational exposure are provided in GSG-7 [24].

#### *3.3.3.4. Workers' health surveillance*

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

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.

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 workers subject to such exposure to ionizing radiation, as there are no diagnostic tests that yield information that is relevant for exposure under normal working conditions. It is therefore rare for considerations of occupational exposure arising from the working environment of a veterinary radiation facility to influence

significantly decisions about the fitness of workers to undertake work with radiation, or to influence the general conditions of service [24].

Special investigations involving biological dosimetry and further extended diagnosis and medical treatment would be necessary only if workers were exposed at doses much higher than the dose limits (e.g. doses of a few hundred millisieverts or higher) [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 any 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 or who may be pregnant. Counselling is to be given by appropriately qualified and experienced practitioners. Further guidance is given in GSG-7 [24] and Ref. [28].

### **3.3.4. Conditions of service and special arrangements**

As established in para. 3.111 of GSR Part 3 [2], 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.

#### *3.3.4.1. Female workers who are pregnant*

GSR Part 3 [2] does not establish a requirement for a female worker to notify her employer of her suspected pregnancy. However, it is necessary for the employer to ensure that all female workers understand the importance of making such notifications and their right to be protected so that their working conditions may be modified accordingly (see para. 3.113). Paragraph 3.113(b) of 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.

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

The limitation of the dose to the embryo or fetus does not mean that a female worker who is or who may be pregnant is required to avoid work with

radiation. Her employer is, however, required to carefully review the working conditions with regard to exposure and potential exposure for female workers who have notified the employer of a suspected pregnancy.

A possible adaptation is the reassignment of a female worker who is pregnant to duties in which the likelihood of an accident or other incident is lower, or 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 information and training.

When the dose limit for public exposure 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 up to 10. The dose to the fetus may be monitored by using an additional dosimeter appropriately positioned [23, 24]. Information, advice and, if indicated, counselling needs to be made available for female workers who are or who may be pregnant.

#### *3.3.4.2. Persons under 18 years of age*

In many States, there is a possibility that students aged 16 or 17 who are undertaking studies and training to become a veterinary technologist may be subject to exposure. Paragraph 3.116 of GSR Part 3 [2] 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, Section 2.2.3).

#### **3.3.5. Education, information, instruction and training**

General guidance concerning education, training, qualification and competence of veterinary professionals is presented in Section 2.5. The following 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. They also include training for operating specific equipment used for diagnostic imaging and interventional radiology in a veterinary facility, and training 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 is augmented by use of the equipment manual. Descriptions of best practice procedures can be found in the scientific literature.

The HERCA Guidelines [4] are an example of education and training in radiation protection for veterinary professionals and are included in the Annex. The HERCA Guidelines [4] include tables on core learning outcomes in radiation protection for veterinary practitioners and on additional learning outcomes

for veterinary practitioners working in the field of interventional radiology. These two tables set out the relevant knowledge, skills and competences for veterinary practitioners.

The HERCA Guidelines [4] also include tables on core learning outcomes in radiation protection for veterinary radiographers and veterinary assistants and on additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of interventional radiology. These two tables set out the relevant knowledge, skills and competences for veterinary technologists.

The HERCA Guidelines [4] note that the requirements for education and training need to be met before veterinary professionals start to work with radiation. They also note that veterinary radiographers and veterinary assistants do not have to meet all the requirements set out in them, depending on the scope of practice and the degree of autonomy that they are permitted in their State.

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

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

### 3.4. RADIATION PROTECTION OF THE PUBLIC

#### **3.4.1. Visitors to the facility, animal owners and the public**

Public exposure of persons in and around the veterinary radiation facility may arise from the performance of veterinary radiology. The requirements of GSR Part 3 [2] for protection of the public apply to veterinary radiation facilities (see paras 3.117–3.123, 3.125–3.127 and 3.135–3.137). This section provides guidance specific to veterinary radiation facilities.

Paragraph 3.78 of GSR Part 3 [2] requires all visitors, including persons delivering goods or supplies, sales personnel, accompanying persons and escorts, as well as animal owners in the facility, to be afforded the same level of protection against exposure as members of the public. Visitors to the veterinary radiation facility will include animal owners accompanying animals to the facility. Such visitors may sit in a waiting room and may travel along corridors to consulting

rooms. Special consideration, in all cases, needs to be given to women who are or who may be pregnant and to all persons who are under the age of 18 years. 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.

#### *3.4.1.1. Protection against public exposure*

The primary means for protecting members of the public, such as visitors, against exposure is the shielding in place at the veterinary radiation facility. The shielding needs to be sufficient that any public exposure resulting from being in any area immediately adjacent to the X ray room that is accessible to visitors would be in compliance with the dose limits for public exposure. This includes rooms both above and below the X ray room and areas outdoors. 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, 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 local rules and procedures need to be established and communicated for access to controlled areas and supervised areas by animal owners. In situations where exposure occurs where the animal housed, the same rules apply.

Access by visitors to X ray rooms and other controlled areas is restricted. Exceptionally, a visitor, for example a veterinary surgeon 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 veterinary radiation facility needs to have written procedures specifying where and when such exceptions can be made and who may accompany the visitor. Special consideration, in all cases, needs 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 to prevent inadvertent entry to areas where diagnostic radiological procedures or image guided interventional procedures are being performed (see paras 3.88 and 3.89 of GSR Part 3 [2], and SSG-46 [20]). Signs and warning lights, conspicuously positioned, need to be placed 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 [19]. 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.

### **3.4.2. Monitoring and reporting of public exposure**

Requirements 30 and 32 and paras 3.127 and 3.137 of GSR Part 3 [2] establish requirements in respect of the monitoring, assessment, recording and reporting of public exposure that apply to the licensee of a veterinary radiation facility. In a veterinary radiation facility, procedures are required to be in place to ensure that:

- (a) The requirements with regard to public exposure are complied with and such exposure is assessed.
- (b) Appropriate records are kept of the results of monitoring programmes.

The monitoring programme for public exposure arising from veterinary radiation facilities needs to include dose assessment for exposures in the areas in and around the X ray rooms that are accessible to the public.

The dose assessment can be carried out on the basis of the shielding calculations made at the planning stage. The estimated doses can be combined with results from area monitoring at the stage of initial operation of the facility and periodically thereafter. Records of dose assessments need to be kept for a period of time that meets any relevant regulatory requirements, and in any case for a period of at least 7–10 years. The dose limits for public exposure are set out in Table 1, Section 2.2.3.

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

### **4.1. GENERAL**

Section 4 covers veterinary medicine using unsealed sources (i.e. veterinary nuclear medicine). Unsealed sources are radioactive materials that are administered to animals for diagnosis or for treatment of disease. X ray imaging, such as in computed tomography, which may be done in conjunction with a procedure in veterinary nuclear medicine 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 to form 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 therapy are usually labelled with alpha, beta or beta-gamma emitting radionuclides.

### **4.2. SAFETY OF VETERINARY NUCLEAR MEDICINE FACILITIES**

#### **4.2.1. Veterinary nuclear medicine facilities**

Provision for the incorporation of radiation safety features is best made at the design stage of 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 procedures within a larger facility. Consideration needs to be given to providing easy exit 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;
- Storage area for radioactive waste.

An example of the layout of a veterinary nuclear medicine facility is shown in Fig. 13. Examples of rooms for the 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 in a veterinary nuclear medicine facility are subject to meeting the requirements established in GSR Part 3 [2] for controlled areas, as well as complying with local regulations (see Requirement 24 and paras 3.88–3.91). These include requirements for:

- 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;
- Provision of facilities for personal decontamination.

It is best practice to have separate rooms for the preparation of radiopharmaceuticals, storage of radiopharmaceuticals, imaging and animal holding. This is often not possible, however, and areas for these purposes may instead be delineated within a single room with shielding applied 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 they 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 where they are being held.

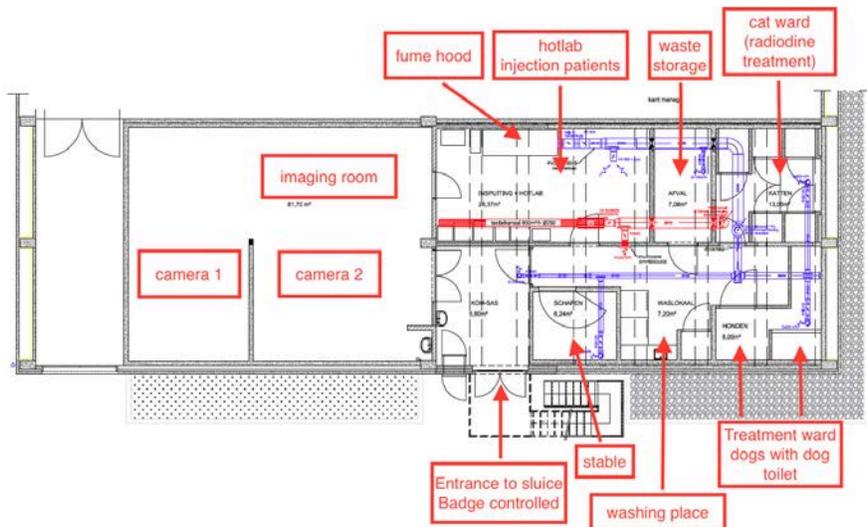


FIG. 13. Example of a layout of a veterinary nuclear medicine facility. The rooms for animals are separated from the imaging (scanning) rooms. There is a separate room for the hot lab and a room for the storage of radioactive waste. Animals are injected in the hot lab. There is a separate room for cats undergoing radioiodine treatment for hyperthyroidism. There is separate room for dogs undergoing radionuclide therapy, with a separate toilet for them. 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.



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 veterinary surgeon, the helper and the anaesthetist. (Courtesy of the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)



*FIG. 15. Cow undergoing a bone scan for a suspected sacroiliac condition. (Courtesy of the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*



*FIG. 16. The use of lead aprons is indicated to reduce the exposure of veterinary surgeons and of helpers when 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 the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*



*FIG. 17. Veterinary room for dogs treated with radioactive compounds (e.g. radioactive iodine for thyroid cancer). This space is created to limit contamination of the room and any items in it. 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. The teddy bear will need to be surveyed and if contaminated will need to be disposed of as radioactive waste. (Courtesy of the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*



*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. (Courtesy of Royal Veterinary College, London.)*

#### 4.2.1.1. *Areas where unsealed sources are handled*

Dedicated work areas for the 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 radioactive waste.

Materials for preventing contamination as well as for remediating it need to be kept available in place. Their specific design and construction need to follow national regulations and need to be discussed with the local authorities. Ideally, a separate room will be available for preparing the radiopharmaceuticals and a separate room will be needed for imaging. When a separate room is not available, adequate shielding, measures to prevent contamination and measures for regulation of the room's climate 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<sup>12</sup> of (i.e. removal of regulatory control from) 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 to be exchanged is to be from areas of low levels of contamination by airborne radioactive material to areas where contamination by airborne radioactive material 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,

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<sup>12</sup> 'Clearance' is defined as the removal of regulatory control by the regulatory body from radioactive material or radioactive objects within notified or authorized facilities and activities. Removal from regulatory control in this context refers to regulatory control applied for radiation protection purposes. Conceptually, clearance — freeing certain materials or objects in authorized facilities and activities from further control — is closely linked to, but distinct from and not to be confused with, exemption — determining that controls do not need to be applied to certain sources and facilities and activities [3]. This is not to be confused with 'clearance' defined as the net effect of the biological processes by which radionuclides are removed from a tissue, organ or area of the body [3].



*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 the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*

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.  $^{131}\text{I}$ ) and facilities housing treated animals need to be appropriately equipped with a negative pressure ventilation system.

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 (i.e. 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 of (i.e. removal of regulatory control from) waste material that is no longer considered to be radioactive waste. Recommendations and guidance are provided in IAEA Safety Standards Series No. SSG-45, *Predisposal Management of Radioactive Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education* [29].

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, properly marked and ventilated. Records need to be kept that identify the origin and content 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 that need to be collected in separate containers to prevent injuries;
- Amounts of radionuclide generator;
- Clothing from stables and kennels (for therapeutic applications of radiopharmaceuticals);
- Liquid scintillation solutions.



*FIG. 20. A storage room for radioactive waste. Contaminated waste needs to be stored separately, preferably in a separate room. Walls and floors need to be washable and non-porous. The transitions between wall and floor need to be seamless. Note the piping of the ventilation system at the ceiling to maintain negative pressure and to prevent internal contamination of workers.*

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 (e.g. in terms of volume, shielding and leaktightness).

In practice, it is mainly  $^{131}\text{I}$  and radioactive waste from animals undergoing therapy with radiopharmaceuticals that need special precautions. Appropriate storage and transport of radioactive waste to allow for decay below the clearance level will minimize any environmental impact of its subsequent release.

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

radioactive 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 as follows:

- (a) Technetium generators. There are two options: (i) returning technetium generators to the supplier after use, ensuring compliance with IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material [17]; and (ii) 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 the preparation and injection of radiopharmaceuticals. When the container is full, it is sealed. The expected date of clearance of (i.e. the removal of regulatory control from) the container 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 or local regulations.
- (c) Vials containing residues of  $^{18}\text{F}$ ,  $^{67}\text{Ga}$ ,  $^{131}\text{I}$ ,  $^{89}\text{Sr}$  and  $^{99\text{m}}\text{Tc}$ . A procedure similar to the one for syringes can be established for vials, but segregation on the basis of physical half-life is necessary.
- (d) Gloves, cover paper and plastic overshoes. Gloves, cover paper and plastic overshoes can be collected in plastic bags in rooms used for the preparation and injection of radiopharmaceuticals. When a bag is full, it is sealed. After an appropriate period of time to allow 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. If sources cannot be cleared, they must be shipped back to the manufacture or, if not available, to a radioactive waste facility in the country. For this, funds need to be available for proper disposition.

- (f) Small amounts of tritium ( $^3\text{H}$ ) and  $^{14}\text{C}$  in organic solutions. Small amounts of tritium and  $^{14}\text{C}$  in organic solutions can usually be dealt with as conventional (non-radioactive) waste. The regulatory authority establishes the limits for this type of disposal. In certain instances, because of their potential toxicity, special precautions may apply, and appropriate precautions for biohazards 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  $^{131}\text{I}$  because of the nature and half-life of the radionuclides. For therapeutic veterinary medicine, policies vary for different States, 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 to allow for decay (usually  $^{99\text{m}}\text{Tc}$ , 60 hours), or else collected and held in dedicated containers in dedicated waste storage facilities for the necessary period of time for decay.

#### 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 dose 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’; that is, 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, which typically include:

- Attenuation by the animal is usually not considered;
- Decay of short lived radionuclides such as  $^{18}\text{F}$  is not considered;
- Workload, use and occupancy factors are overestimated;
- The persons to be protected are considered to remain where their exposure is highest in the adjacent room throughout the procedure.

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. Purchase of equipment*

The performance of gamma cameras (planar and single photon emission computed tomography systems) and positron emission tomography scanners determines 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 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 nuclear medicine, as appropriate, and the radiation protection officer.

The following specifications are important with regard to the performance of the detector for gamma cameras:

- Analysis of pulse height;
- Uniformity;
- Spatial resolution and linearity;
- Energy resolution;
- Sensitivity;
- Count rate performance;
- 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 that of  $^{99m}\text{Tc}$  (140 keV) are used, dedicated collimators have to be in place. Sodium iodide crystals are hygroscopic and sensitive to temperature fluctuations, which necessitates control of the room for temperature and humidity.

The following specifications are important for the performance of cameras for positron emission tomography:

- Spatial resolution;
- Sensitivity;
- Scatter fraction, count losses and random measurements;
- Energy resolution;
- Image quality and accuracy of attenuation, scatter correction and quantitation;
- Resolution of coincidence timing for the accuracy of time of flight positron emission tomography.

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.

When purchasing hybrid systems, based on a combination with computed tomography, it is advisable to ensure that the equipment meets the relevant technical standards of the International Electrotechnical Commission, the International Organization for Standardization<sup>13</sup>, or equivalent national standards [20, 21]. Specifications concerning computed tomography can be found in Section 3.

#### 4.2.2.2. *Ancillary equipment*

The veterinary nuclear medicine facility needs to have equipment, instruments and test objects for reference, for measurements, for quality control and for relative dosimetry. 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, the International Organization for Standardization or equivalent national standards. Further guidance on appropriate equipment, instruments and test objects is given in Refs [30–33].

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<sup>13</sup> Up to date lists of the current standards are available at [www.iec.ch](http://www.iec.ch) and [www.iso.org](http://www.iso.org)

The veterinary nuclear medicine facility needs to be equipped with properly calibrated and maintained instruments for radiation monitoring, 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.

Animal positioning devices such as supports and sandbags may be necessary. These need to be made of materials that are 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.

#### 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



*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. (Courtesy of Royal Veterinary College, London.)*

of para. 3.53 of GSR Part 3 [2]. Guidance on the security of sealed sources is provided in Ref. [18].

In a veterinary nuclear medicine facility, sources include unsealed sources such as radiopharmaceuticals, as well as radionuclide generators, equipment for dispensing radiopharmaceuticals, and sealed sources used for calibration or quality control tests (see ISO 3925:2014, Unsealed Radioactive Substances: Identification and Documentation [34]). Activities that are critical with regard to the 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 [18].

The licensee of the veterinary nuclear medicine 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 the theft, loss and unauthorized withdrawal of radioactive materials and the entry of unauthorized personnel to controlled areas. The licensee of the veterinary nuclear medicine facility is required to maintain a detailed 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 (see para. 3.53 of GSR Part 3 [2]).

It is necessary to develop written procedures to encourage 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*

GSR Part 3 [2] establishes requirements for the 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 proper functioning of equipment is essential to the efficacy of diagnostic procedures and therapeutic procedures. Maintenance and servicing of radiological equipment need to be included in the quality assurance programme. Maintenance and servicing are usually performed by appropriately authorized engineers or technicians employed either by a company offering such services (which may be the manufacturer or the vendor) or by the veterinary facility itself. Maintenance and servicing of equipment need to be carried out at intervals recommended by the manufacturer or by the regulatory body. While equipment is under servicing, it is not to be used until the service has been completed, tested and proper functioning is verified.

Maintenance programmes need to cover components of hardware and equipment, including their electrical and mechanical systems, and software components, including networks, databases and other software systems

supporting the hardware. The engineer or technician carrying out maintenance and servicing needs to follow the rules for radiation protection, rules for general health and safety, and the procedures established by the employer, as well as the rules and procedures of the veterinary nuclear medicine facility. Records of completed maintenance (both 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. These reports are to be archived as part of the quality assurance programme.

### 4.3. OCCUPATIONAL RADIATION PROTECTION

#### 4.3.1. General

In veterinary nuclear medicine, workers subject to exposure based on their access to controlled and supervisor areas are usually veterinary surgeons 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 radiotherapy services, are also subject to occupational exposure.

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

Section 4 provides guidance on radiation protection specific to veterinary nuclear medicine. More general and comprehensive recommendations and guidance on occupational radiation protection that are applicable to all areas of use of radiation (including non-veterinary and non-medical uses) are provided in GSG-7 [24], which includes recommendations and guidance on radiation protection programmes, on assessment of occupational exposure and on providers of dosimetry services.

## 4.3.2. Arrangements under the radiation protection programme

### 4.3.2.1. Classification of areas

Various areas and rooms in a veterinary nuclear medicine facility are required to be designated and classified as controlled areas or supervised areas, in accordance with Requirement 24 and paras 3.88–3.92 of GSR Part 3 [2]. Once designated, these areas are subject to the requirements established in paras 3.89 and 3.90 (for controlled areas) and paras 3.91 and 3.92 (for supervised areas). These include requirements for:

- 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;
- Provision of facilities for personal decontamination.

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

The entrance to a scintigraphy room (a controlled area) is shown in Fig. 22. In a veterinary nuclear medicine facility, rooms for the 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



*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. (Courtesy of Royal Veterinary College, London.)*

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 in the vicinity of 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. Radiation levels in the vicinity of the control panel may

nevertheless be very low owing to the design of the 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 these areas, where possible, need to be 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: 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, which are to be augmented by administrative controls and personal protective equipment (see Requirements 21, 22 and 24 and corresponding paras 3.76(g), 3.83(b), 3.93 and 3.95). The local rules will encompass procedures relating to:

- The ordering, transport and receipt of radiopharmaceuticals;
- The unpacking, storage, preparation and administration of radiopharmaceuticals to animals;
- The examination and treatment of animals and the care of treated animals;
- The storage and handling of associated radioactive waste.

To this end, and as required in GSR Part 3 [2], written local rules and procedures are to be established for a veterinary nuclear medicine facility. The purpose of the local rules and procedures is to ensure protection and safety for operators and other persons (see Requirement 24 and paras 3.90(d) and 3.94). 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.

The local rules need to include measures for the optimization of protection and safety for occupational exposure, both in normal work and in abnormal conditions. Local rules and procedures also need to cover the wearing, handling and storage of personal dosimeters, and to specify investigation levels<sup>14</sup> and follow-up actions. The local rules are to be readily accessible, for example, on

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<sup>14</sup> An ‘investigation level’ is defined as the value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation would be conducted [3].

signs hung on doors giving access to certain parts of the controlled areas (e.g. the 'hot lab'). It is advisable to develop standard operating procedures for each procedure in veterinary nuclear medicine and to make periodic reviews.

All persons involved in using radiation in veterinary nuclear medicine need to know and to follow the local rules and procedures. The development and review of local rules and procedures may involve the radiation protection officer and a qualified expert in radiation protection.

Equipment (hardware and software) is to be operated or used 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 regard. Additional procedures also need to be considered to provide easy access to readily understandable information on the functioning of the equipment. The final documented set of operational procedures is to be approved by the licensee of the veterinary nuclear medicine facility and incorporated into the facility's quality management system.

Staff working in veterinary nuclear medicine need to understand the documented standard operating procedures and the operation of the equipment with which they are working, including its safety features, 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. This includes the procedures for dealing with incidents that could lead to external or internal contamination, including spillages of radioactive material. Additional training needs to be provided when new radiopharmaceuticals or new devices are to be used or when new equipment is installed in the veterinary nuclear medicine facility. These procedures are focused on minimizing external exposure as well as contamination, both their occurrence and their spread. All manipulation for dispensing radioactive material needs to be carried out over a drip tray 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.  $^{131}\text{I}$ ) needs to be performed under a fume hood or a similar ventilated device with appropriate filters to prevent contamination of adjacent rooms and the environment. The preparation and dispensing of radiopharmaceuticals need 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 mobile 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 before opening for contamination. 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.

Animals will be sedated for imaging procedures unless their condition poses a risk. Sedation is sometimes not necessary for very short procedures (e.g. thyroid scans or kidney scans).

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.

Containers such as lead pots that no longer contain radioactive material after measurement and clearance, may be dealt with as conventional (non-radioactive) waste. Any radiation warning labels need to be removed or obliterated after clearance of (i.e. removal of regulatory control from) the containers. Figure 23 shows a 'hot lab' in a veterinary nuclear medicine facility.

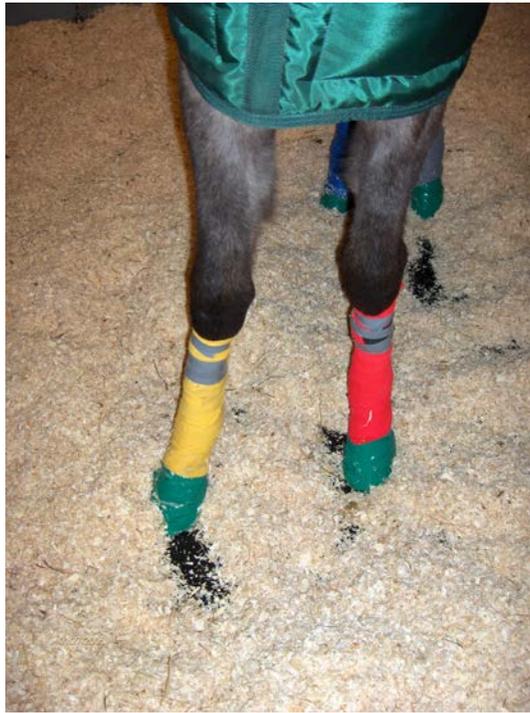


*FIG. 23. A 'hot lab' in a veterinary nuclear medicine facility. Manipulation of radioactive material is performed under a fume hood. L-block shielding is present. Note the filter system for trapping airborne radioactive material to the right side of the fume hood. Use of a filter system is mandatory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

#### *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 lead shielded syringe is preferable unless this hampers injection to an undesirable degree. Protective clothing is generally unlikely to be necessary for persons accompanying animals into gamma camera rooms. An exception is for the scanning of horses, for which it might be beneficial for the animal handler to wear a lead apron [35, 36].

Spread of contamination by a horse on its way from the stable to the scintigraphy room can be minimized by the use of leg coverings when it is in the stable. Before injection of the radionuclide, the horse's legs and feet are protected with bandages and tape to prevent contamination of its legs and feet and contamination of the floor by urine (see Fig. 24). The bandages and tape are removed outside the stable when the horse leaves it prior to the scintigraphy procedure.



*FIG. 24. Wood shavings are used as bedding in the stable to absorb the urine of horses. Bandaging the horse's legs and covering the feet with tape reduces contamination of the horse's legs by urine. (Courtesy of Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*

Plastic bags are used to cover the horse's feet to avoid contamination of the ground by urine between the stable and the scintigraphy room (see Fig. 25). Clearly labelled buckets on long handles need to be available to be used to catch urine during transit of the horse between the stable and the scintigraphy room, and in the scintigraphy room, to prevent contamination by urine (see Fig. 26). When contamination (usually contamination by urine) occurs, the necessary remedial actions will depend on the amount spilled. Procedures for dealing with spillages of radioactive material and with decontamination of persons are provided in Appendix II.

On leaving the controlled area, workers need to deposit 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; by



*FIG. 25. A horse's foot in a plastic bag after injection of the radionuclide. Bags are used to cover the horse's feet to avoid contamination of the ground by urine between the stable and the scintigraphy room. (Courtesy of Royal Veterinary College, London.)*



*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.*

protective aprons that are not lead based, it is even less. The use of automatic dispensers and injectors and mobile shields affords more effective ways to reduce exposure of the operator.

Operators, animal handlers and, where necessary, animal owners need to be kept as far as possible from the animal during the acquisition of images. In this regard, animals will be sedated or anaesthetized for the imaging procedure when possible and when safe for the animals (i.e. unless their condition poses a risk). For the 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 to indicate 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 containers with 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 and administrations and of management of radioactive waste.

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

#### *4.3.2.5. 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 the dose constraints for occupational exposure. For some therapies, it is advisable to use other protective equipment (e.g. gloves, shoe covers or step-off pads).

For oral administrations of radiopharmaceuticals in therapy, 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

specific demands of the particular therapy. Clear instructions need to be provided in the form of standard operating procedures and orally. The training needs to cover radiation protection and local rules, in particular for situations in which there is a risk of contamination from urine, faeces or vomit.

The construction of rooms and stables need to follow the same guidelines as for other parts of the controlled area. Floors and ceilings need to be washable and resistant to chemical changes, and they 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 (see Figs 24 and 25). Such rooms and stables would not be cleaned until all radionuclides present had decayed sufficiently.

Non-essential animal care needs to be minimized to reduce the dose to animal handlers, operators and veterinary surgeons. 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 veterinary care of the animal is a priority and need not be delayed, it may be necessary to restrict the amount of time that a veterinary surgeon spends with the animal. It may be necessary to have a risk assessment carried out by a qualified expert in radiation protection.

Access to animals to which radiopharmaceuticals have been administered needs to be restricted to veterinary surgeons and handlers directly involved in the procedure, who need to be clearly informed of the radiation risks and procedures to be followed. Protective clothing, such as laboratory coats, gloves and shoe covers, is to be provided at the entrance to the rooms and stables and is to be used. When the wearer leaves the rooms and stables, used protective clothing needs to be removed, bagged and stored until the radioactive material has been measured and verified that it has decayed.

The dose rate from animals needs to be measured prior to their release to ensure that regulatory release criteria are met. Animals can be released when dose rates or activity concentrations meet the criteria for public exposure that are 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 or who may be pregnant or who are breastfeeding.

It may be necessary to delay the release of animals from the veterinary facility or to issue special instructions for conditions when they are released. The

owner of an 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 giving instructions is provided in Appendix III.

#### *4.3.2.6. Decontamination of persons as described in the rules and procedures in the management system*

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 at removing it. 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 [33]. Further information is provided in Appendix II.

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 avoid radioactive material entering the eyes, nose or mouth. If the skin is broken or if a wound is sustained under conditions where there is a risk of 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 needs 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 given adequate training in the procedures for dealing with incidents, spillages of radioactive material and contaminated persons. Refresher training needs to be given at appropriate intervals. The training needs to include instructions on appropriate washing, showering and eye washing.

#### *4.3.2.7. 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 and public radiation protection (see Requirements 21, 22 and 24 and

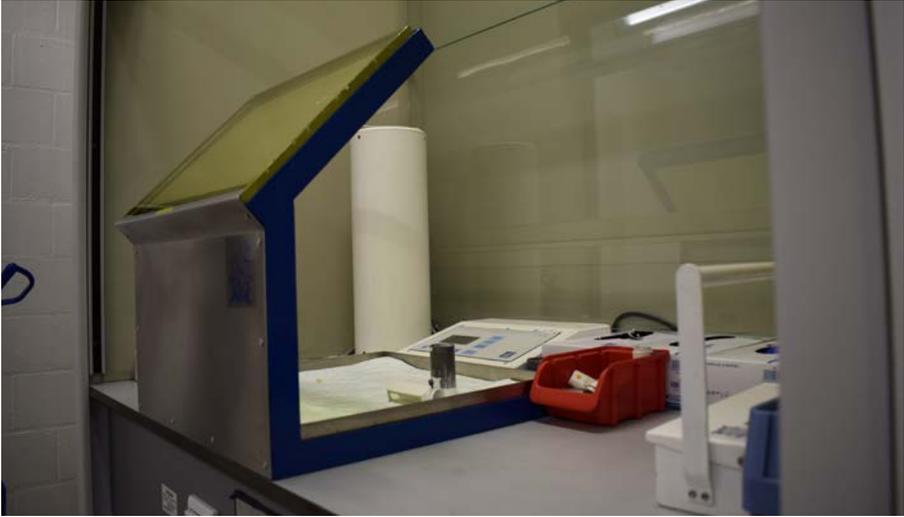
corresponding paras 3.76(g), 3.83(b), 3.93 and 3.95). For a veterinary nuclear medicine facility, protective equipment could include the following:

- (a) Shields (i.e. L-blocks and side blocks) for bench tops, vials, syringes and activity meters and for the preparation of radiopharmaceuticals 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 for the administration of radiopharmaceuticals. Protective clothing may include laboratory gowns or overalls, waterproof gloves (made of latex or of non-latex material such as neoprene, polyvinyl chloride or nitrile), shoe covers or dedicated shoes to be worn in the restricted area, 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 it needs to be removed before the wearer leaves the 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 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  $^{99m}\text{Tc}$ . However, 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) [35, 36]. Lead aprons need to be periodically checked for tears or cracks in the lead.
- (d) Tools, including tongs and forceps, for remote handling of radioactive material.
- (e) Containers for radioactive waste and for transport of radioactive sources.

#### 4.3.2.8. *Monitoring of the workplace*

Requirement 24 and paras 3.90 and 3.96–3.98 of GSR Part 3 [2] set out the requirements and responsibilities for monitoring of the workplace. Monitoring of the workplace for radiation levels is necessary to ensure protection and safety, and it is used to minimize exposure of workers. Workplace monitoring needs to be performed and records need to be maintained as part of the veterinary nuclear medicine facility's radiation protection programme (see paras 3.96–3.101 of GSR Part 3 [2]).

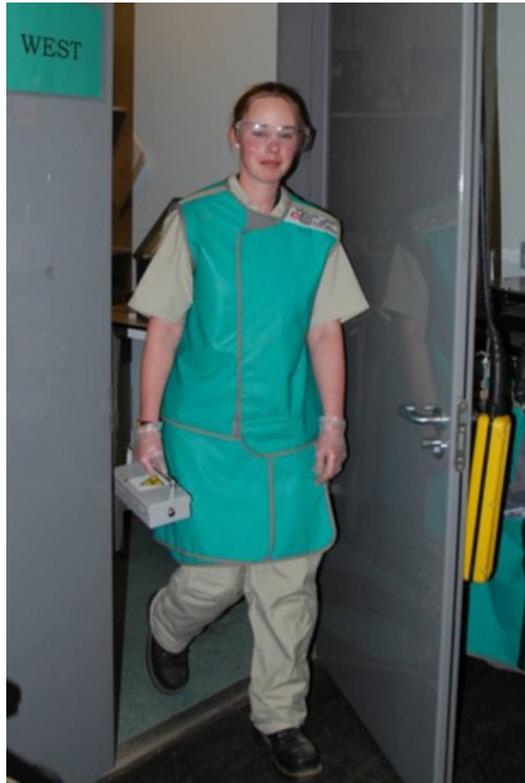
Workplace monitoring comprises the taking of measurements in the working environment and interpretation of the results, assessment, investigation and reporting. Workplace monitoring serves several purposes, including routine



*FIG. 27. Detail of the working space. 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.*



*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 the Department of Medical Imaging and Small Animal Orthopaedics, Faculty of Veterinary Medicine, Ghent University.)*



*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 ( $^{99m}\text{Tc}$ ) in a lead lined box. (Courtesy of Royal Veterinary College, London.)*

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 especially important for staff members who do not have individual monitoring. General recommendations and guidance on workplace monitoring are given in GSG-7 [24]. Workplace monitoring can lead to corrective measures being recommended, if necessary.

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 after investigation levels have been exceeded [2]. At a 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, 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**

#### *4.3.3.1. Individual monitoring for assessment of occupational exposure*

Paragraphs 3.99–3.102 of GSR Part 3 [2] require 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 who may receive a significant dose from occupational exposure. The dose limits of GSR Part 3 [2] for occupational exposure and for public exposure are presented in Table 1, Section 2.2.3.

Workers for whom individual monitoring may be required include:

- Professionals in veterinary nuclear medicine;
- Veterinary radiation technologists;
- Radiation protection officer;
- Pharmacists for radiopharmaceuticals;
- Any persons involved in the preparation, dispensing and administration to animals of radiopharmaceuticals for diagnosis and therapy;
- Staff dealing with radioactive waste;
- 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 persons 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 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 person in that veterinary facility.

Personal dosimeters are worn for specific monitoring periods that are specified by the regulatory body in most States. The monitoring period (i.e. period of use of a dosimeter) is typically in the range of one to three months. The monitoring period is determined by such factors as availability for service, workload and type of work.

A one month monitoring period is typically used for personnel 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 for most persons 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 higher 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, reading 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  $H_p(10)$ <sup>15</sup>, provides a good estimate of the contribution to the effective dose of the parts

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<sup>15</sup>  $H_p(10)$  is the personal dose equivalent  $H_p(d)$  in soft tissue below a specified point on the body at a depth  $d$  of 10 mm. This parameter is used as a directly measurable proxy (i.e. substitute) for equivalent dose in tissues or organs or (with  $d = 10$  mm) for effective dose, in individual monitoring of external exposure. The recommended value of  $d$  is 10 mm for strongly penetrating radiation [3].

of the body protected by the apron, but underestimates the contribution to the effective dose of the unprotected parts of the body (the thyroid, the head and neck, and the extremities).

- (b) A single dosimeter worn over (i.e. 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 means of an appropriate algorithm [37–39].
- (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 monitoring and internal monitoring. Paragraph 3.102 of GSR Part 3 [2] requires employers to ensure that workers who could be subject to exposure due to contamination are identified and are responsible for arranging for appropriate monitoring (see also GSG-7 [24]).

When not in use, personal dosimeters need to be kept in a dedicated place. They need to be protected from damage and from irradiation. If a person loses his or her personal dosimeter, the person needs to inform the radiation protection officer. The radiation protection officer needs to perform a dose assessment, record this evaluation of the dose and add it to the person'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 a person's dose is to use his or her recent dose history. In cases where the person performs non-routine types of work, it may be better to use the doses of co-workers having similar exposure conditions as the basis for the dose estimate.

Additional direct reading operational dosimeters, such as electronic dosimeters, may be considered for use in a veterinary nuclear medicine facility, for example in a new facility or new department or with the introduction of new procedures. Such devices can give the worker an instant indication of both the cumulative dose and the current dose rate. The official dosimeter of record is the personal dosimeter assigned to the individual. The devices 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.

#### *4.3.3.2. Investigation levels for workers*

Investigation levels are different from dose constraints and dose limits. 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 need to be carried out and corrective actions need to be taken when the dose received by a worker exceeds an investigation level.

In veterinary nuclear medicine, predetermined values such as pro rata monthly doses greater than 0.5 mSv for effective dose or 15 mSv per month for hand dosimeters or finger dosimeters could be used as investigation levels [26, 27]. 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 pre-set value above a historical average.

Abnormal conditions or unusual events also necessitate 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. Recommendations and guidance on investigation levels are provided in GSG-7 [24].

An investigation needs to be initiated as soon as possible following the exceedance of an investigation level or abnormal conditions or an incident (see paras 1.31, 3.45–3.48 and 3.94 of GSR Part 3 [2]). A written report needs to be prepared concerning: the cause; the determination and 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 as described in regulations.

#### *4.3.3.3. 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 (see paras 3.103–3.107 of GSR Part 3 [2]).

As well as for demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary nuclear medicine 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. Paragraph 3.106(a) of GSR Part 3 [2] requires employers to provide workers with access to records of their own occupational exposure.

Further general recommendations and guidance on records of occupational exposure are provided in GSG-7 [24].

#### *4.3.3.4. Workers' health surveillance*

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

No specific workers' health surveillance relating to radiation exposure is necessary for staff involved in veterinary nuclear medicine.

Under normal working conditions, the doses incurred due to occupational exposure in veterinary nuclear medicine are low. No specific radiation related examinations are necessary for workers subject to such exposure to ionizing radiation, as there are no diagnostic tests that yield information that is relevant for exposure under normal working conditions. It is therefore rare for considerations of occupational exposure arising from the working environment of a veterinary nuclear medicine facility to influence significantly decisions about the fitness of workers to undertake work with radiation, or to influence the general conditions of service [24].

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

In the event of suspected internal contamination, additional investigations to determine the uptake and retention of radionuclides may be necessary. Interventions to facilitate excretion or to limit the uptake of radionuclides may also need to be considered.

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 any workers who are concerned about their radiation exposure. In veterinary nuclear medicine, workers who are concerned about their radiation exposure may include female workers who are or who may be pregnant or breastfeed. Counselling is to be given by appropriately qualified and experienced practitioners. Further guidance is given in GSG-7 [24] and Ref. [28].

#### **4.3.4. Conditions of service and special arrangements**

As established in para. 3.111 of GSR Part 3 [2], 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.

#### *4.3.4.1. Female workers who are pregnant or breastfeeding*

GSR Part 3 [2] does not establish a requirement for a female worker to notify her employer of her suspected pregnancy or that she is breastfeeding. However, it is necessary for the employer to ensure that all female workers understand the importance of making such notifications and their right to be protected so that their working conditions may be modified accordingly (see para. 3.113). Paragraph 3.113(b) of 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.

The employer of a female worker, who has been notified by the female worker of her suspected pregnancy or that she is breastfeeding, 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 (see para. 3.114 of GSR Part 3 [2]).

The limitation of the dose to the embryo or fetus does not mean that a female worker who is or who may be pregnant or who is breastfeeding is required to avoid work with radiation. Her employer is, however, required to carefully review the working conditions with regard to exposure and potential exposure for female workers who have notified the employer of a suspected pregnancy or of breastfeeding. For example, a female worker who is pregnant may be restricted from spending time in the radiopharmacy or from working with radioiodine solutions [28, 40], which if ingested could cross the placental barrier and could concentrate in the fetal thyroid.

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

#### 4.3.4.2. *Persons under 18 years of age*

In many States, there is a possibility that students aged 16 or 17 who are undertaking studies and training to become a veterinary technologist may be subject to exposure. Paragraph 3.116 of GSR Part 3 [2] 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, Section 2.2.3).

#### 4.3.5. **Education, information, instruction and training**

General guidance concerning education, training, qualification and competence of veterinary professionals is presented in Section 2.5. The following is additional guidance that is applicable to veterinary professionals working in veterinary medicine using unsealed sources.

The objectives of the training include imparting knowledge of risks associated with radiation and mechanisms of risk reduction. They also include training for operating specific equipment used for veterinary nuclear medicine in a veterinary facility, and training 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 is augmented by use of the equipment manual. Descriptions of best practice procedures can be found in the scientific literature.

The HERCA Guidelines [4] are an example of education and training in radiation protection for veterinary professionals and are included in the Annex. The HERCA Guidelines [4] include tables on core learning outcomes in radiation protection for veterinary practitioners (veterinary surgeons) and on additional learning outcomes for veterinary practitioners working in the field of veterinary nuclear medicine. These two tables set out the relevant knowledge, skills and competences for veterinary practitioners.

The HERCA Guidelines [4] also include tables on core learning outcomes in radiation protection for veterinary radiographers and veterinary assistants and on additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of veterinary nuclear medicine. These two tables set out the relevant knowledge, skills and competences for veterinary technologists.

The HERCA Guidelines [4] note that the requirements for education and training need to be met before veterinary professionals start to work with radiation. They also note that veterinary radiographers and veterinary assistants do not have to meet all the requirements set out in them, depending on the scope of practice and the degree of autonomy that they are permitted in their State.

Veterinary practitioners (veterinary surgeons) need to be given the responsibility for providing information, instruction and training to other staff

in the veterinary facility. These other staff include veterinary nurses and animal handlers who may be required to assist in the performance of procedures in veterinary nuclear medicine, to participate in the management of animals to which radiopharmaceuticals have been administered, and to clean rooms and stables after the animals to which radiopharmaceuticals have been administered have left the veterinary facility.

Veterinary practitioners (veterinary surgeons) who may also be the radiation protection officer, also need to be given the responsibility for providing information, instruction and training to other staff in the veterinary facility on the risks relating to the use of radiation, on the areas with restricted access (controlled areas and supervised areas), and on general safety issues.

Veterinary practitioners (veterinary surgeons) need to be given the responsibility for providing appropriate information to animal owners on the procedures that are carried out on their animals. Veterinary practitioners also need to be given responsibility for providing instructions and information to the owners of animals to which radiopharmaceuticals have been administered who are allowed to manage them on their release. An example of such giving instructions is provided in Appendix III.

#### 4.4. RADIATION PROTECTION OF THE PUBLIC

##### 4.4.1. Visitors to the facility, animal owners and the public

Public exposure of persons in and around the veterinary nuclear medicine facility and of animal owners may arise from the performance of veterinary nuclear medicine. The requirements of GSR Part 3 [2] for protection of the public apply to veterinary nuclear medicine facilities (see paras 3.117–3.123, 3.125–3.127 and 3.135–3.137). This section provides guidance specific to veterinary nuclear medicine facilities.

Paragraph 3.78 of GSR Part 3 [2] requires all visitors, including persons delivering goods or supplies, sales personnel, accompanying persons and escorts, as well as animal owners in the facility, to be afforded the same level of protection against exposure as members of the public. Visitors to the veterinary nuclear medicine therapy facility will include animal owners accompanying animals to the facility. Such visitors may sit in a waiting room and may travel along corridors to consulting rooms. Special consideration, in all cases, needs to be given to women who are or who may be pregnant and to all persons who are under the age of 18 years.

The animal owner is not allowed to be present when the animal is undergoing procedures in veterinary nuclear medicine. The instructions to be

given to animal owners with regard to public exposure and the release of animals are provided in Appendix III.

Persons who are required to be afforded protection against public exposure include the wider public involved with the animals. In addition, there is a possibility, albeit low, of public exposure via exposure pathways associated with the management of radioactive waste. Public exposure in the wider public domain could also occur as a result of the release from the veterinary nuclear medicine facility of animals to which radiopharmaceuticals have been administered and are still incorporated.

#### *4.4.1.1. Protection against public exposure*

The radiation protection officer of the veterinary nuclear medicine facility, in consultation with the regulatory body, needs to establish rules for protection against public exposure following the release of an animal that has undergone therapy with radiopharmaceuticals. GSR Part 3 [2] requires that doses from any such public exposures be below the dose limits for public exposure and, preferably, lower than any applicable dose constraint.

Animal owners need to be provided with detailed information and written instructions concerning the precautions to be taken in order to keep exposures for themselves, their family members and other members of the public below the dose limits for public exposure. Special consideration, in all cases, needs to be given to women who are or who may be pregnant, and to all persons who are under the age of 18 years in the animal's surroundings. In particular, the instructions to owners need to cover the management of radioactive waste following the release of an animal after the use of radionuclides for diagnostic procedures or therapy.

For owners of cats, contaminated cat litter needs to be kept in a separate place, for a period of a time that will depend on the radionuclide used. For owners of dogs, voiding and defecation by dogs needs to be restricted to places where the presence of the public is as limited as possible (i.e. not in dog parks or in other public places).

For owners of horses or other large animals, information needs to be provided with regard to 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.

#### 4.4.1.2. *Control of access*

Access by visitors to rooms at the veterinary nuclear medicine facility is restricted to persons who are accompanied by certain staff members. These need to be staff members who are involved in procedures performed at the facility and are informed about relevant issues in and measures for radiation protection.

Access to areas where unsealed sources are 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 local rules and procedures need to be established and communicated for access to controlled areas and supervised areas by animal owners.

Signs, conspicuously positioned, need to be used at the entrances to 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 [19].

#### **4.4.2. Monitoring and reporting of public exposure**

Requirements 30 and 32 and paras 3.127 and 3.137 of GSR Part 3 [2] establish requirements in respect of the monitoring, assessment, recording and reporting of public exposure that apply to the licensee of a veterinary nuclear medicine facility. In a veterinary nuclear medicine facility, procedures are required to be in place to ensure that:

- (a) The requirements with regard to 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 monitoring programmes.

The monitoring programme for public exposure arising from veterinary nuclear medicine facilities needs to include dose assessment for exposures in the areas in and around the veterinary nuclear medicine facility that are accessible to the public.

The dose assessment can be carried out on the basis of the shielding calculations made at the planning stage. The estimated doses can be combined with results from area monitoring and contamination monitoring at the stage of initial operation of the facility and periodically thereafter. Records of dose assessments need to be kept for a period of time that meets any relevant regulatory requirements, and in any case for a period of at least 7–10 years. The dose limits for public exposure are set out in Table 1, Section 2.2.3.

## 4.5. PREVENTION OF ACCIDENTS AND MITIGATION OF THEIR CONSEQUENCES

### 4.5.1. Safety assessment

To comply with the requirements for safety assessment in paras 3.29–3.36 of GSR Part 3 [2], the licensee is required to conduct a safety assessment to be applied to all stages of the design and operation of the veterinary nuclear medicine facility and provide for periodic review of safety. A report on the safety assessment is to be submitted to the regulatory body if so required. The safety assessment needs to deal essentially with determining ‘what could go wrong’ and how it could be prevented, and, if something does ‘go wrong’, how its consequences could be mitigated.

The safety assessment for a veterinary nuclear medicine facility has to be systematic, has to identify events that could lead to potential exposure, and has to consider their likelihood and potential consequences. Paragraph 3.34 of GSR Part 3 [2] requires that the safety assessment be documented.

The safety assessment needs to cover events, causes and contributory factors identified following reported accidents in veterinary nuclear medicine facilities and to be comprehensive. It also needs to anticipate possible events that have not previously been reported, and it should not be restricted to the consideration of incidents that have occurred. Consideration needs to be given to using systematic techniques, for example fault tree analysis, event tree analysis and techniques of probabilistic safety assessment.

The safety assessment needs to be revised: (i) when new or modified sources, including equipment, and new or renovated facilities are introduced; (ii) when operational change occurs, including changes in workload; (iii) when operational experience or information on accidents or errors indicates that the safety assessment needs to be reviewed.

In safety assessments for veterinary nuclear medicine facilities, all steps in the use of radiopharmaceuticals for diagnosis and treatment need to be considered. These steps include:

- Ordering, transport and receipt of radiopharmaceuticals;
- Unpacking, storage, preparation and handling of radiopharmaceuticals;
- Administration of radiopharmaceuticals to animals;
- Examination and treatment of animals;
- Care of treated animals;
- Storage and handling of radioactive waste.

#### **4.5.2. Prevention of accidents**

Prevention of accidents is the best means of avoiding potential exposure. Paragraphs 3.39–3.42 of GSR Part 3 [2] establish requirements for good engineering practice, defence in depth and facility based arrangements to prevent accidents. Defence in depth is a hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions [3]. Design considerations for the veterinary nuclear medicine facility and its equipment are described in Section 4.2.

The licensee needs to include measures for defence in depth to cope with possible events identified in the safety assessment. Measures identified in the evaluation of the reliability of the safety systems (including administrative procedures and operational procedures, and the design of the facility and of equipment) also need to be included. For example, the theft of sources can be minimized by having multiple layers of security, including keeping sources locked up in a room that is also in an area to which access is restricted. Information on these measures needs to be included in programmes for education and training, and for maintenance and quality assurance.

Operational experience and lessons identified from accidents and errors also provide valuable information. This information also needs to be included in programmes for training, maintenance and quality assurance.

The behaviour of animals and their unexpected actions can lead to accidents during radiological procedures for diagnosis and treatment. All efforts need to be made to minimize accidents involving animals, to make use of animal restraints, including measures for sedation, and to adopt practices for keeping exposures ‘as low as reasonably achievable’. In addition, animal handlers need to be appropriately trained for the responsibilities of their work. Veterinary surgeons and animal handlers need to be aware of animal behaviours that could affect radiation protection measures and that could cause incidents. Specific considerations may be necessary for the prevention of accidents in specific imaging and treatment modalities.

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

As stated in para. 1.20 of GSR Part 3 [2], if an event or a sequence of events that has been postulated and considered in the assessment of risks (safety assessment) does occur, it will need to be treated either as a planned exposure situation or, if an emergency has been declared, as an emergency.

On the basis of events identified in the safety assessment for the veterinary nuclear medicine facility, procedures for response actions need to be prepared for possible incidents giving rise to potential exposure. These procedures need to include:

- The allocation of responsibilities and resources;
- The persons responsible for taking actions, with full contact details (contact details, e.g. for the radiation protection officer, need to be posted conspicuously throughout the facility);
- The development and adoption of procedures;
- The provision of training and periodic retraining for relevant staff in taking response 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 that are commensurate with the hazards assessed and with the potential consequences of accidents and other incidents need to be established, as appropriate. Procedures for response actions in a veterinary nuclear medicine facility include, but are not limited to, the following information:

- (a) Accidents and other incidents, including those of low probability, and actions to deal with them;
- (b) The persons responsible for taking actions, with full contact details (contact details for such people, e.g. for the radiation protection officer, need to be posted throughout the facility);
- (c) The responsibilities of individual personnel in taking response actions and following procedures for an emergency;
- (d) Equipment and tools necessary to take the response actions and to follow the procedures for an emergency;
- (e) Training and periodic exercises;
- (f) Recording and reporting systems;
- (g) Immediate measures to avoid unnecessary radiation exposure of staff and the public;
- (h) Measures to prevent access of persons to affected areas;
- (i) Measures to prevent spread of contamination, including leakage from fume hoods and ventilation systems;
- (j) Notification of the event to the regulatory body if reporting thresholds have been exceeded;
- (k) Investigation procedures.

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

- (a) Protective clothing, for example overshoes and gloves;
- (b) Materials for decontamination of affected areas, 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 facilities and workers engaged in emergency procedures are required to be protected against occupational exposure. Doses from occupational exposure in planned situations of exposure are required to be kept within the dose limits for occupational exposure. If, in an emergency, it is considered justified for the dose limits to be exceeded, however, the workers involved in the response to an incident will be considered to be emergency workers. The requirements for preparedness and response for an emergency established in paras 4.1–4.21 of GSR Part 3 [2] and in IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency [41], and the recommendations and guidance provided in GSG-7 [24] will apply.

#### *4.5.3.1. Damage to radionuclide generators*

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

- (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 contamination; to specify the boundaries of a cordoned off area for the purposes of safety; and to supervise procedures for decontamination and monitoring, including determining when restrictions on entering the cordoned off area can be lifted.
- (c) Record details of the incident, investigation and corrective actions and make a report to the regulatory body.

#### 4.5.3.2. *Spillage of radioactive material*

Procedures for dealing with a spillage of radioactive material and with decontamination of persons are provided in Appendix II.

#### 4.5.3.3. *Urgent veterinary attention to animals to which radiopharmaceuticals have been administered in therapy*

Veterinary emergencies may necessitate the urgent care of animals to which radiopharmaceuticals have been administered in therapy. In such cases, dose rates near the animals can be high. Measures need to be taken to minimize exposure of the staff attending such animals. All staff members need to wear impermeable protective gloves and need to be informed about 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 if 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 minimize 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 the inventory of sources (see Section 4.2.2.3) is maintained and is kept up to date by the radiation protection officer of the veterinary medicine facility (see para. 3.53 of GSR Part 3 [2]). It can then be determined immediately whether a source is missing. In the event of the loss of a source, it can be determined which source is missing, its type and activity, its last known location and when it was there, and who last took possession of it.

A proactive attitude is important when 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, contact the shipper and manufacture of the source and inform them of the failure to arrive so that they can trace the shipment and determine where the source is;
- (f) If the source is still not found, report the loss of the source according to the rules established 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 the safe evacuation of visitors and staff and, when possible, of animals. When the first responders (e.g. the fire services) are summoned and attend, they need to be informed of the presence of radioactive material and the presence of animals.

No one, other than emergency responders, may enter or re-enter the building until it has been checked for contamination by the radiation protection officer or by the radiation safety staff of the agency in charge of emergency response. Requirements are established and recommendations and guidance on the arrangements for dealing with emergencies are provided in GSR Part 7 [41] and IAEA Safety Standards Series No. GS-G-2.1, Arrangements for Preparedness for a Nuclear or Radiological Emergency [42].

## 4.6. SAFETY IN THE TRANSPORT OF RADIOACTIVE MATERIAL

Paragraph 2.25 of GSR Part 3 [2] establishes requirements on the transport of radioactive material, invoking in particular SSR-6 (Rev. 1) [17], which uses 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 to mean any package or packages, or load of radioactive material, presented by a consignor for transport [17].

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 (e.g.  $^{14}\text{C}$  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 packaging and packages; test procedures; and approval and administrative requirements — are established in SSR-6 (Rev. 1) [17].

Emergency arrangements for the transport of radioactive material need to be put in place, in line with the requirements of GSR Part 7 [41] and the regulations, 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 be able 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 in which ionizing radiation (teletherapy, brachytherapy), either alone or in combination with other modalities, is used 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 the guidance typically provided for a medical facility in which people undergo radiation therapy [20]. Guidance specific to veterinary use is also provided in this publication, where appropriate. In applications of veterinary medicine, equipment and sources for radiation therapy can be used and operated only under the direct authority of the radiation protection officer such as the veterinary surgeons who are properly trained and accredited to perform or to delegate such work [4].

Radiotherapy equipment for use in veterinary medicine can be bought new from manufacturers, or it can be bought second hand from brokers or directly from (human) medical radiotherapy facilities, in order to reduce the costs of its installation. 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 designed and manufactured specifically for use in veterinary radiology, there is currently no radiotherapy equipment designed and

manufactured specifically for veterinary use. Currently radiotherapy equipment developed for human use is used for veterinary radiotherapy.

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 guidance on the design features of medical radiological equipment are provided in SSG-46 [20].

External beam radiation therapy (teletherapy) is usually performed with linear accelerators producing high energy (megavolt) photon or electron beams. Cobalt-60 units are going out of use in many States. Superficial and orthovoltage units producing low and medium energy (kV) X rays are also found in veterinary medicine. External beam radiation therapy for veterinary medicine follows advances in medical 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;
- Intraoperative radiotherapy.

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

Other in-room image guided radiotherapy devices using ionizing radiation are low energy (kV) X ray sources that can produce digital radiography, tomotherapy (megavoltage 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 animal's body. In some instances, low dose rate sources may be introduced manually.

Pulsed dose rate brachytherapy equipment is increasingly being used in medical brachytherapy. Such techniques are of no use in veterinary brachytherapy, 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 compliance with requirements for radiation protection as simple as possible. In locating a new veterinary radiation therapy facility, 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 or with an increased workload, all need to be considered.

Radiation therapy rooms are often located on the periphery of a veterinary facility. This is to minimize difficulties arising with radiation protection as a consequence of 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 environment also needs to be considered in siting, for example, whether the site is adjacent to residential or industrial areas, whether there is public access, and other uses of land in the surrounding area. These considerations all relate to ensuring that public exposure outside the veterinary radiation therapy facility — and above and below it if these areas are occupied — 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 veterinary radiation therapy facility: General considerations*

A veterinary radiation therapy facility typically comprises the following areas: reception; consulting areas; area for external beam radiation therapy; brachytherapy area (including a storage area for sources); imaging area; and

treatment planning area. Provision for the incorporation of radiation safety features into these areas is best made at the design stage of the facility.

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 with higher energy machines, such as when a  $^{60}\text{Co}$  unit is replaced with a linear accelerator.

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

The design of the facility needs to include consideration of an air-conditioning system sufficient to maintain the temperature and humidity in the treatment room. The temperature and humidity need to be maintained within the parameters specified by the manufacturers of the equipment. They also need to be consistent with any requirements for the control of temperature and humidity for human occupancy for purposes of health and safety. In addition, a ventilation system with four to six air changes per hour is advisable for removing any ozone generated by radiation [43].

The workload and the staff need to be taken into account in the layout. Wherever possible, treatment rooms need to be surrounded with rooms that have low occupancy or controlled occupancy. Information on radiation protection in the design of radiotherapy facilities is provided in Ref. [44].

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.

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

Firefighting equipment needs to be kept 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 [45].

### *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 in the veterinary radiation therapy facility need to be carried out 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 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 equipment for anaesthesia. There needs to be sufficient space for staff to walk around the room and for safety procedures to be followed (e.g. to maintain 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 in replacing a  $^{60}\text{Co}$  unit with a higher energy linear accelerator, or the installation of a non-isocentric unit, for instance. Information on radiation protection in the design of radiotherapy facilities is provided in Ref. [44].

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 allowed in the room while an animal is being treated.

#### *5.2.1.4. Design of rooms in the veterinary radiation therapy facility: Manual brachytherapy and low dose rate brachytherapy*

Rooms used for storage, preparation and implantation of sealed radioactive sources for brachytherapy have to be designed for safety. Appendix IV provides guidelines on the 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 of sealed sources 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 or the stable, and to reduce the risk of movement or loss of the brachytherapy implant. In the rooms 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, or at the exit from, the treatment area to detect a low dose rate source, or an animal with a source, leaving the room or the controlled area. The area radiation monitor can also be used to confirm that a high dose rate source is back in its 'in-safe' position inside

the afterloading unit (in the room) (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, in addition to the area radiation monitor, needs to be available for monitoring these items.

5.2.1.5. *Design of rooms in the veterinary radiation therapy facility:  
Considerations relating to shielding*

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. [44].



FIG. 30. An area radiation monitor placed at the entrance to or exit from the treatment area to detect a low dose rate source, or an animal with a source, leaving the room or the controlled area. The area radiation monitor can also be used to confirm that a high dose rate source is back in its 'in-safe' position inside the afterloading unit (in the room). (Courtesy of Vetotech, Villeneuve d'Ascq.)

Second hand medical radiotherapy equipment is often bought for use in veterinary radiotherapy. In many cases, modifications are made to the equipment to take into account the constraints on shielding the room. For example, a barrier needs to be incorporated to disable use of the highest photon energy in a dual megavolt energy machine to ensure that the equipment can only be used at the energy for which the room was designed. 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 (see Refs [20, 21]).

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**

### *5.2.2.1. Purchase of equipment*

Licensees are required to take responsibility for the radiation safety of the radiological equipment to be used in veterinary radiation therapy facilities (see paras 2.40, 3.38 and 3.42 of GSR Part 3 [2]). Licensees may impose purchasing specifications that include conditions set to meet relevant technical standards of the International Electrotechnical Commission and the International Organization for Standardization, or equivalent national standards. Radiation sources, including radioactive material, equipment and accessories, are to be purchased only from suppliers who meet the national requirements for such dealings.

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

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 radiation therapy professionals, as appropriate, and the radiation protection officer.

When purchasing equipment, it is advisable to ensure that it meets the relevant technical standards of the International Electrotechnical Commission

and the International Organization for Standardization, or equivalent national standards. The International Electrotechnical Commission has issued international technical standards applicable to medical radiological equipment. The International Organization for Standardization also publishes international technical standards applicable to medical radiological equipment. An up to date list of standards of the International Organization for Standardization may be found on its web site.

It needs to be ensured that second hand equipment is considered safe for the people involved and also for the animals, and that it is fit for its intended use with animals (see Section 2.4.2). 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 guidance on the design features of medical radiological equipment are provided in SSG-46 [20]. 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.

#### *5.2.2.2. Design features of veterinary radiological equipment: General considerations*

For the benefit of animals being treated, the design of radiological equipment and the design of procedures (for maintenance and service) need to be such that their performance is always reproducible, accurate and predictable. Radiological equipment used in veterinary radiation therapy facilities is designed and manufactured for radiation therapy for people. It is designed and manufactured as medical radiological equipment as defined in GSR Part 3 [2] and the IAEA Safety Glossary [3].<sup>16</sup> There is no radiotherapy equipment specifically designed for veterinary purposes. Radioactive sources for teletherapy and

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<sup>16</sup> ‘Medical radiological equipment’ is defined as radiological equipment used in medical radiation facilities to perform radiological procedures that either delivers an exposure to 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 <sup>60</sup>Co teletherapy units; to devices used in a medical imaging procedure involving ionizing radiation 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 [3].

brachytherapy need to meet relevant standards of the International Organization for Standardization (see Refs [46–48]).

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) need to be systematically verified for all their functionalities and for data integrity. If parameters are incorrectly introduced into the system, systematic treatment errors will arise. The 'record and verify' system is therefore subject to periodic quality assurance, and detailed guidance can be found in Refs [49, 50]. Recommendations and guidance are also provided in SSG-46 [20].

#### 5.2.2.3. *Design features of veterinary radiological equipment: External beam radiation therapy*

Veterinary radiological equipment used for external beam radiation therapy has to meet the specifications given in the relevant International Electrotechnical Commission standards [51–59]. Guidance on design specifications and performance is provided in Refs [60–63]. The following considerations are included:

- (a) Safety interlocks, or other means designed to prevent the use of the machine in conditions other than those selected at the control panel, are provided.
- (b) The design of equipment permits interruption of the treatment from the control panel; after the interruption of treatment, resumption is possible only from the control panel.
- (c) 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.
- (d) The radiation field within the treatment area in the absence of any modifiers of the radiation beam (i.e. wedges or multileaf collimators) is as uniform as practicable and the non-uniformity is specified by the supplier. The non-uniformity of flattening filter free beams is also specified by the supplier.
- (e) 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.
- (f) 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 (by induced radioactivity as a secondary effect of radiotherapy) of animals and materials in the treatment room [64].

#### *5.2.2.4. Design features of veterinary radiological equipment: Brachytherapy*

Radiological equipment used for brachytherapy needs to meet the specifications given in Ref. [65] and needs to follow the guidance in Refs [60, 66]. Low dose rate sources and high dose rate sources have to be accompanied by a source certificate specifying: (i) the source strength in terms of reference air kerma rate in air or an equivalent quantity as recommended by the International Commission on Radiation Units and Measurements [67], at a specified distance, for a specified date; and (ii) the quality control tests applied to the source, including leakage tests and contamination tests.

Applicators for brachytherapy are manufactured specifically for the source to be used or to be compatible with it. To avoid encapsulation or rupture of the applicator due to radiation damage, sources are never left in the applicators (pre-loaded applicators) between veterinary procedures. When not in use, all brachytherapy sources need to be removed and stored safely and securely. Sources using beta emitters, such as  $^{90}\text{Sr}$  in ophthalmic applicators, are provided with shielding of low atomic number to minimize bremsstrahlung while they are in storage and in preparation for use.

#### *5.2.2.5. 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 requirements of the International Electrotechnical Commission published in Ref. [59] and which can be adapted to the application [68].

#### *5.2.2.6. 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 pretreatment, 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.

#### 5.2.2.7. *Ancillary equipment*

The veterinary radiation therapy facility needs to have equipment, instruments and test objects for reference, for measurements, for quality control and for relative dosimetry that are appropriate for the type of measurement needed for characterization of the beam and for quality control. These 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 [60, 63, 65, 69–71].

Facilities with remote afterloading brachytherapy need to have equipment for source handling in the event of the failure of the afterloading unit, including:

- Storage container in the treatment room to serve as an emergency source container in the event of failure of the afterloading unit in retracting the source;
- Remote manipulator;
- Wire cutters;
- Geiger–Müller tube detector for location of sources.

The veterinary radiation therapy facility needs to be equipped with properly calibrated and maintained instruments for radiation monitoring (area detectors, portable meters, 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. Source handling equipment, including a magnifying glass, source manipulators (e.g. forceps, tweezers, tongs), clippers or wire cutters, and several shielded containers are also necessary.

#### 5.2.2.8. *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 in para. 3.53 of GSR Part 3 [2]. Guidance on the security of sealed sources is provided in Ref. [18].

In a veterinary radiation therapy facility, sources include sealed sources used in teletherapy or brachytherapy. Activities that are critical with regard to the security of sources in a veterinary radiation therapy facility include receipt of sources, storage of sources and movement of sources within the facility [18].

The licensee of the veterinary 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 the theft, loss and unauthorized withdrawal of radioactive material and the entry of unauthorized personnel to controlled areas. The licensee of the veterinary radiation therapy facility is required to maintain a detailed 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 (see para. 3.53 of GSR Part 3 [2]).

#### *5.2.2.9. Maintenance of equipment*

GSR Part 3 [2] establishes requirements for the 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 proper functioning of equipment is essential to the efficacy of diagnostic and therapeutic procedures. Maintenance and servicing of radiological equipment need to be included in the quality assurance programme. Maintenance and servicing are usually performed by appropriately authorized engineers or technicians who understand the specifications of veterinary radiological equipment.

The licensee needs to establish the necessary arrangements for maintenance with the manufacturer's representative when purchasing the equipment. Maintenance and servicing 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 need to be carried out at 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, tested and proper functioning is verified.

Maintenance programmes for radiological equipment need to cover the veterinary radiological equipment and its hardware and software components, including networks, databases, viewing monitors, view boxes and other software systems supporting the hardware in the veterinary radiation therapy facility (e.g. picture archiving and communication systems, radiology information systems).

The maintenance of the radiotherapy equipment and imaging equipment or equipment for the planning of treatment may affect the accuracy of physical and veterinary dosimetry, or the safe operation of the equipment. In such cases, a medical physicist who supports activities in radiation therapy needs to perform

specific tests or measurements to confirm that the equipment is operating satisfactorily before it is used for treating animals.

In addition to ensuring the safety of the X ray generating parts of the radiological equipment, ensuring the safety of the electrical and mechanical parts of the radiological equipment is an important part of the maintenance programme. The safety of the electrical and mechanical parts of the radiological equipment can have direct or indirect effects on radiation safety. These parts need to be included in the maintenance protocol.

The engineer or technician carrying out maintenance and servicing needs to follow the rules for radiation protection, rules for general health and safety, and the procedures established by the employer, as well as the rules and procedures of the veterinary radiation therapy facility. Records of completed maintenance (both 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. These reports are to be archived as part of the quality assurance programme.

#### *5.2.2.10. Protective clothing*

Each radiation 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 need 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 I.

### 5.3. OCCUPATIONAL RADIATION PROTECTION

#### **5.3.1. General**

In veterinary radiation therapy, workers subject to exposure are usually veterinary surgeons, veterinary technologists and veterinary nurses. In addition, there are also medical physicists who support activities in radiotherapy in some facilities by providing advice or by performing treatment planning and quality assurance, routine maintenance procedures and checks. Workers subject to exposure may also include service engineers and some contractors, depending on their duties.

Workers in veterinary radiation therapy facilities who are subject to exposure to radiation from sources that are not required by or directly related

to their work are required to be afforded the same level of protection against exposure as members of the public (see para. 3.78 of GSR Part 3 [2]). Such workers include veterinary nurses, cleaners, administrative personnel, and other service staff and support staff involved in the management of animals. Information needs to be provided to such workers on the relevant safety related aspects and on local rules and procedures. It is therefore required 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.

Section 5 provides guidance on radiation protection specific to radiation therapy. More general and comprehensive recommendations and guidance on occupational radiation protection that are applicable to all areas of use of radiation (including non-veterinary and non-medical uses) are provided in GSG-7 [24], which includes recommendations and guidance on radiation protection programmes, on assessment of occupational exposure and on providers of dosimetry services.

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

- (a) Designing radiation therapy facilities and equipment for best practice in procedures, especially procedures in the use of ancillary devices;
- (b) Correctly selecting radiation therapy procedures on the basis of sound veterinary practice;
- (c) Performing the radiation therapy 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.

### **5.3.2. Arrangements under the radiation protection programme**

#### *5.3.2.1. Classification of areas*

Various areas and rooms in a veterinary radiation therapy facility are required to be designated and classified as controlled areas or supervised areas, in

accordance with Requirement 24 and paras 3.88–3.92 of GSR Part 3 [2]. These include requirements for:

- 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;
- Provision of facilities for personal decontamination.

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.

The following provides 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 of a qualified expert in radiation protection.

Those areas and rooms to be designated and classified as controlled areas or supervised areas include 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. Once designated, these areas are subject to the requirements established in paras 3.89 and 3.90 (for controlled areas) and 3.91 and 3.92 (for supervised areas) of GSR Part 3 [2]. Supervised areas may include areas around brachytherapy rooms and around storage areas and handling areas for radioactive sources.

The area in the vicinity of the control panel for all radiological equipment used in radiation therapy is to be classified as a supervised area. Radiation levels in the vicinity of the control panel may nevertheless be very low owing to the design of the shielding between the panel and the room containing the radiological equipment.

Uncertainties about the extent of the designation of controlled areas and supervised areas need to be avoided. The boundaries of these areas, where possible, need to be walls and doors or other physical barriers. These need to be 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, which are to be augmented by administrative controls and personal protective equipment (see Requirements 21, 22 and 24, and corresponding paras 3.76(g), 3.83(b), 3.93 and 3.95). Shielding is a type of engineered control, and structural shielding is preferred over ancillary shielding.

To this end, and as required in GSR Part 3 [2], written local rules and procedures are to be established for a veterinary radiation therapy facility. The purpose of the local rules and procedures is to ensure protection and safety for operators and other persons (see Requirement 24 and paras 3.90(d) and 3.94). 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.

The local rules need to include measures for the optimization of protection and safety for occupational exposure, both in normal work and in abnormal conditions. Local rules and procedures also need to cover the wearing, handling and storage of personal dosimeters, and to specify investigation levels<sup>17</sup> and follow-up actions. 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. treatment rooms). It is advisable to develop standard operating procedures for each procedure in veterinary radiation therapy and to make periodic reviews.

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

Equipment (hardware and software) is to be operated or used 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 regard. Additional procedures also need to be considered to provide easy access to readily understandable information on the functioning of the equipment. The final documented set of operational procedures is to be approved by the licensee of the veterinary radiation therapy facility and incorporated into the facility's quality management system.

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<sup>17</sup> An 'investigation level' is defined as the value of a quantity such as effective dose, intake or contamination per unit area or volume at or above which an investigation would be conducted [3].

Staff working in veterinary radiation therapy need to understand the documented standard operating procedures and the operation of the equipment with which they are working, including its safety features. They also need to be given adequate training in what to do when things go wrong. Refresher training needs to be given at appropriate intervals. Additional training needs to be provided when new radiological equipment is installed or new techniques are introduced into the facility.

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

For external beam radiation therapy and high dose rate brachytherapy, no one may remain 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  $^{60}\text{Co}$  sources, and the functionality of survey meters need to be checked daily prior to the 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 (see Ref. [47]).

Area surveys need to be performed periodically (e.g. every six months) or as required by the regulatory body in areas around all treatment units and check sources, including  $^{60}\text{Co}$  units, shielded safes, and storage facilities for low dose rate sources, high dose rate sources and sources to be used in permanent implants.

#### *5.3.2.3. Local rules and procedures: External beam radiation therapy*

The 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 radiation monitor;
- Capabilities for leak testing (for radioactive sources);
- Personal alarm dosimeters, especially for unplanned exposures.

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 need to reflect the fact that this phenomenon, if it occurs, can be identified by starting to monitor from outside

the room in which the source is located (i.e. by monitoring from areas of lower dose rates to areas of higher dose rates).

The presence of other persons in the vicinity of the control panel needs to be kept to the minimum necessary so as to avoid distractions to the operator.

Irradiations that involve long periods of use of high energy X rays, such as beam calibration, dosimetry and quality control measurements, need to be scheduled to take place at the end of the treatment day or during weekends. Neutron activated radionuclides (especially longer lived ones) can then decay significantly overnight.

Animals that are receiving external beam radiation therapy treatment, both small animals such as dogs and cats, and large animals such as horses, may be anaesthetized and strictly immobilized when being treated 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 accelerator teletherapy). Note the positioning cushion and ties. (Courtesy of Vetotech, Villeneuve d'Ascq.)*



*FIG. 32. Dog under general anaesthesia in external beam radiation therapy (electron beam teletherapy). (Courtesy of Vetotech, Villeneuve d'Ascq.)*



*FIG. 33. Dog undergoing total body irradiation in external beam radiation therapy (linear accelerator). (Courtesy of North Carolina State University, Raleigh.)*

#### 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, in transit or in use. Facilities for the storage of sources are to be marked to warn that they contain radioactive materials. Contact details (e.g. for the radiation protection officer) for use in an emergency need to be posted conspicuously throughout the facility 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 need to be removed from the animal, accounted for and replaced 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. [72].

#### 5.3.2.5. *Local rules and procedures: Brachytherapy, additional guidance 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 needs 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 period and/or separation distance allowance for veterinary technologists and visitors;
- Use of mobile shielding, where available;
- Concise instructions for unplanned removal of the source and applicator, and for dealing with an emergency;
- Contact details (e.g. for the radiation protection officer).

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

Reusable sources need to be visually inspected 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 location of each source within the safe to reduce the time taken to locate and identify sources.

Sources are to be handled only 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 or a long-handled trolley can be used (see Fig. 34).



*FIG. 34. When transporting low dose rate 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 can be used. The same container can also be used as emergency equipment for the placement of a high dose rate source if the source becomes stuck during a treatment. Note the wire cutters on the container. (Courtesy of Vetotech, Villeneuve d'Ascq.)*

Reusable sources that come into direct contact with body tissues need to be cleaned and sterilized 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 used as the applicator loading room, it may have a sink for cleaning the applicators. However, this could lead to the loss of a source to the sewerage system if an applicator put in the sink is still loaded with a source. 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 guide and the radioactive source. Continuous sedation during the period of treatment may only be necessary if the behaviour of the animal is of concern, and if there is a risk that its behaviour could affect the treatment by removing or damaging the implant.

Regular surveillance of animals to which radiopharmaceuticals have been administered and are still incorporated is necessary by the means of direct visual examinations and camera monitoring. In some cases, difficult behaviour of an animal could be considered 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 guidance for high dose rate sources*

For brachytherapy treatments at high dose rates, animals may be anaesthetized, or heavily sedated, only for the implantation of the treatment guide and the radioactive source, as well as during each treatment session. General anaesthesia may be given in the treatment room to prevent the movement of the animal. It is recommended for small companion animals (typically cats and dogs), whereas heavy sedation can be appropriate for larger animals (e.g. horses), provided that a monitoring camera is used during treatment (see Fig. 35).

In cases where only sedation is being used, attention needs to be paid to minimizing the movements of connecting cables and minimizing tension between the animal and the afterloading unit. The afterloading unit 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 when the source is being retracted between two implantations to allow a direct veterinary evaluation of the state of sedation and anaesthesia of the animal. The state of anaesthesia or the state of sedation of the animal during treatment may be uncertain. In such



*FIG. 35. Horse undergoing high dose rate brachytherapy. Note that the horse is sedated. (Courtesy of Vetotech, Villeneuve d'Ascq.)*

cases, it is necessary to interrupt treatment immediately to allow for retraction of the source and direct evaluation of the state of anaesthesia or sedation of the animal. Once the state of anaesthesia or the state of sedation has been evaluated and modified as necessary, the brachytherapy treatment can be resumed.

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

The high dose rate afterloading unit needs to undergo routine quality assurance tests at the beginning of each treatment day [72].

Under the emergency plan, an emergency container needs to be kept available in the treatment room. The emergency container needs to be sufficiently large that it can accept the entire applicator assembly containing the source that has been removed from an animal. The emergency container also needs to be placed close to the animal. Staff need to be trained in how to follow such a procedure and need to participate in regular drills and exercises.

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 be returned to the safe, or for other actions for retrieval of the source.

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

- (a) Observation at the console of an error message and emergency indicators (audible and visible alarms);
- (b) Recovery at the console (e.g. pressing an emergency off button, emergency stop button or emergency source retract button);
- (c) Entry into the room with a portable radiation survey meter (opening the door activates the interlock that retracts the source);
- (d) Observation of radiation levels in the room (by means of mounted monitors or portable survey meters);
- (e) Recovery at the afterloading unit (pressing an emergency off button, emergency stop button or emergency source retract button on the remote afterloading unit);
- (f) Manual retraction of the source (using a hand crank);
- (g) Survey of the animal and survey of the afterloading unit (to confirm that the source is in the safe);
- (h) Removal of the applicator and placement in the emergency container;
- (i) 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);
- (j) Removal of the animal from the vault with subsequent redundant survey monitoring;
- (k) Informing the personnel responsible for maintenance of the afterloading unit, the radiation protection officer and, depending on its rules and regulations, 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 (e.g. a pre-established colour). These unique identifiers need to be marked by means that cannot be degraded by body fluids. This marking is for visual recognition and to avoid the possibility of confusion between different

sources or batches. Containers used for the transport of radioactive sources are subject to the requirements established in SSR-6 (Rev. 1) [17].

All movements of sources are to be recorded, with the signature of the person responsible for the move. The licensee needs to designate a person to be accountable for 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 visually inspected for possible damage after each use by means of magnifying viewers and a leaded viewing window in a shielded work area. Sources are to be handled only 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 or a long-handled trolley can be used (see Fig. 34). Reusable sources that come into direct contact with body tissues need to be cleaned and sterilized 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 $^{192}\text{Ir}$ wires*

During the cutting and handling of  $^{192}\text{Ir}$  wires, the following conditions need to be met:

- (a) There is good illumination of the work surface.
- (b) Appropriate tools and equipment such as forceps, cutting devices and magnifying glasses are available and are used.
- (c) If  $^{192}\text{Ir}$  wires are cut off for immediate use, a container to hold cut lengths is provided and labelled.
- (d) Radioactive waste is collected and stored in adequate containers, and is properly transferred to another appropriate licensee or to an authorized waste disposal facility.
- (e) 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 given in Sections 3 and 4. Additional information relevant to local rules specific to using imaging equipment as part of image guided radiotherapy is given in Ref. [73].

#### *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 (see Requirements 21, 22 and 24 and corresponding paras 3.76(g), 3.83(b), 3.93 and 3.95). The need for protective equipment has to be established by the veterinary radiation therapy facility's radiation protection officer or by a qualified expert in radiation protection.

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

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 animals treated with either temporary brachytherapy implants of low dose rate sources or permanent brachytherapy implants, consideration may be given to the use of movable shielding in the room [73]. Protective equipment for emergencies in brachytherapy, for example, if a source is lodged in at a high dose rate, needs to include an emergency container suitable for applicators and sources.

#### *5.3.2.11. Monitoring of the workplace*

Requirement 24 and paras 3.90 and 3.96–3.98 of GSR Part 3 [2] set out the requirements and responsibilities for monitoring of the workplace. Monitoring of the workplace for radiation levels is necessary to ensure protection and safety, and it is used to minimize exposure of workers. Workplace monitoring needs to be performed and records need to be maintained as part of the veterinary nuclear medicine facility's radiation protection programme (see paras 3.96–3.101 of GSR Part 3 [2]).

Workplace monitoring comprises the taking of measurements in the working environment and interpretation of the results, assessment, investigation and reporting. 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 especially important for staff members who do not have individual monitoring. General recommendations and guidance on workplace monitoring are given in GSG-7 [24]. Workplace monitoring can lead to corrective measures being recommended, if necessary.

The veterinary radiation therapy 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 after investigation levels have been exceeded [2].

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

- (a) Construction of the room and the shielding has been completed, either new or in a renovation, and before the room is first used for veterinary purposes.
- (b) New or substantially refurbished equipment is commissioned.
- (c) Source replacements have taken place in teletherapy or in remote controlled brachytherapy.
- (d) New software for veterinary radiological equipment is installed or there has been a significant upgrade to existing software.
- (e) New techniques are introduced.
- (f) Servicing has been performed on radiological equipment that may affect the delivery of radiation.

Initial workplace monitoring includes measurements of radiation leakage from equipment, and of radiation levels in the accessible areas around, above and below irradiation rooms, by using suitable phantoms. This initial workplace monitoring needs to be performed as part of acceptance testing, prior to the veterinary use of the 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 means of permanently installed area monitors. The area for storage and handling of sources needs to be monitored with a survey meter immediately following the removal from storage or the return to storage of brachytherapy sources.

For treatment rooms where there is a possibility of induced activity, for example 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 emitted from induced radionuclides in the treatment room [64, 74].

Workplace monitoring needs to be done in association with brachytherapy procedures. Soon after implantation of the brachytherapy sources into an animal under treatment, 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 as the dose equivalent quantity. For radiation therapy procedures, the appropriate ambient dose equivalent is  $H^*(10 \text{ mm})$  in units of sieverts, with multiplier scales. The calibration needs to be current and needs to be 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**

#### *5.3.3.1. Individual monitoring for assessment of occupational exposure*

Paragraphs 3.99–3.102 of GSR Part 3 [2] require 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 who may receive a significant dose from occupational exposure. The dose limits of GSR Part 3 [2] for occupational exposure and for public exposure are presented in Table 1, Section 2.2.3.

Workers for whom individual monitoring may be required include:

- Veterinary practitioners;
- Veterinary radiation oncologists;
- Medical physicists;
- Radiation protection officer;
- Maintenance and servicing personnel;
- Any technical staff or other staff who spend time with animals that have brachytherapy implants of sealed sources.

Personal dosimeters are assigned to persons 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 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 person in that veterinary facility.

Monitoring results can then be interpreted for the person working in a specific veterinary radiation therapy facility. This will allow for appropriate review of the effectiveness of the optimization of protection and safety for that person in that facility. However, national regulations and regulatory requirements may differ from this advice, and these would need to be followed in those jurisdictions in which they apply.

Personal dosimeters are worn for specific monitoring periods that are specified by the regulatory body in most States. The monitoring period (i.e. period of use of a dosimeter) is typically in the range of one to three months. The monitoring period is determined by such factors as availability for service, workload and type of work.

A one month monitoring period is typically used for personnel 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 for most persons 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, reading and reporting of 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 veterinary radiation therapy: the dose limit for effective dose, and the dose limits for equivalent dose to the lens of the eye; and equivalent dose to the 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 upper front of the torso. This is because 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 doses to the finger are necessary, the manufacturer's specific instructions for wearing them need to be followed.

When not in use, personal dosimeters need to be kept in a dedicated place. They need to be protected from damage and from irradiation. If a person loses his or her personal dosimeter, the person needs to inform the radiation protection officer. The radiation protection officer needs to perform a dose assessment, record this evaluation of the dose and add it to the person'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 a person's dose is to use his or her recent dose history. In cases where the person performs non-routine types of work, it may be better to use the doses of co-workers having similar exposure conditions as the basis for the dose estimate.

Additional direct reading operational dosimeters, such as electronic dosimeters, may be considered for use in a veterinary radiation therapy facility, for example in a new facility or 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. The official dosimeter of record is the personal dosimeter assigned to the individual. The devices 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. 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 need to be carried out and corrective actions need to be taken when the dose received by a worker exceeds an investigation level.

In radiation therapy for example, pro rata monthly doses greater than 0.5 mSv (for the dosimeter worn on the torso) necessitate an investigation. Doses greater than 15 mSv per month for hand dosimeters or finger dosimeters also could be used as investigation levels [26, 27].

Abnormal conditions or unusual events also necessitate 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. Recommendations and guidance on investigation levels are provided in GSG-7 [24].

An investigation needs to be initiated as soon as possible following the exceedance of an investigation level or abnormal conditions or an incident (see paras 1.31, 3.45–3.48 and 3.94 of GSR Part 3 [2]). A written report needs to be prepared concerning: the cause; the determination and 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 as described in regulations.

#### *5.3.3.3. 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 (see paras 3.103–3.107 of GSR Part 3 [2]).

As well as for demonstrating compliance with legal requirements, records of occupational exposure are used within the veterinary radiation therapy 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. Paragraph 3.106(a) of GSR Part 3 [2] requires employers to provide workers with access to records of their own occupational exposure. Further general recommendations and guidance on records of occupational exposure are provided in GSG-7 [24].

#### *5.3.3.4. Workers' health surveillance*

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

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

Under normal working conditions, the doses incurred due to occupational exposure in veterinary radiation therapy are low. No specific radiation related examinations are necessary for workers subject to such exposure to ionizing radiation, as there are no diagnostic tests that yield information that is relevant for exposure under normal working conditions. It is therefore rare for considerations of occupational exposure arising from the working environment of a veterinary radiation therapy facility to influence significantly decisions about the fitness of workers to undertake work with radiation, or to influence the general conditions of service [24].

Special investigations involving biological dosimetry and further extended diagnosis and medical treatment would be necessary only if workers were exposed at doses much higher than the dose limits (e.g. doses of a few

hundred millisieverts or higher) [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 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 or who may be pregnant. Counselling is to be given by appropriately qualified and experienced practitioners. Further guidance is given in GSG-7 [24] and Ref. [28].

#### **5.3.4. Conditions of service and special arrangements**

As established in para. 3.111 of GSR Part 3 [2], 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.

##### *5.3.4.1. Female workers who are pregnant*

GSR Part 3 [2] does not establish a requirement for a female worker to notify an employer of her suspected pregnancy. However, it is necessary for the employer to ensure that all female workers understand the importance of making such notifications and their right to be protected so that their working conditions may be modified accordingly (see para. 3.113). Paragraph 3.113(b) of 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.

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

The limitation of the dose to the embryo or fetus does not mean that a female worker who is or who may be pregnant is required to avoid work with radiation. Her employer is, however, required to carefully review the working conditions with regard to exposure and potential exposure for female workers who have notified the employer of a suspected pregnancy. For example, the dose to the fetus for a female worker who is pregnant and who is involved in handling sources in manual brachytherapy, under normal conditions, may reach

the dose limit for public exposure (see Table 1, Section 2.2.3). 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 in which the likelihood of an accident or other incident is lower, or to a location that may have a lower ambient dose equivalent. Such reassignments need to be accompanied by adequate information and training. A further consideration is the need to avoid including a female worker who is or who may be pregnant in the response to an accident or in emergency response, such as responses to incidents similar to those described in Section 5.5.3, for example incidents with a  $^{60}\text{Co}$  unit or a high dose rate brachytherapy unit.

When the dose limit for public exposure 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 of 10 for low energy X rays and by a factor of about 2 for  $^{60}\text{Co}$  and MeV X rays. The dose to the fetus may be monitored by using an additional dosimeter appropriately positioned [23, 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 a possibility that students aged 16 or 17 who are undertaking studies and training to become a veterinary technologist may be subject to exposure. Paragraph 3.116 of GSR Part 3 [2] 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, Section 2.2.3).

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

The practice of radiation therapy is a planned operation. When circumstances result in accidents or other 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 situation. The potential exposure may be considered in advance and response actions need to be developed accordingly.

Exposure of staff responding to incidents is subject to the dose limits for occupational exposure, unless an emergency has been declared. Response actions for the consequences of incidents include considerations for the optimization of protection and safety for the workers responding to the incidents. The response actions include allocation of responsibilities. They also provide for the education

and training of the relevant staff in taking the response actions, which need to be periodically exercised. Most incidents in a veterinary radiation therapy facility, for example the retraction of a high dose rate source, can be dealt with in a planned manner so that occupational exposures and the doses received can be kept low (see Section 5.5.3).

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

General guidance concerning education, training, qualification and competence of veterinary professionals is presented in Section 2.5. The following 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. They also include training for operating specific equipment used for diagnostic imaging and interventional radiology in the veterinary facility, and training 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 is augmented by use of the equipment manual. Descriptions of best practice procedures can be found in the scientific literature.

The HERCA Guidelines [4] are an example of education and training in radiation protection for veterinary professionals and are included in the Annex. The HERCA Guidelines [4] include: tables on core learning outcomes in radiation protection for veterinary practitioners (veterinary surgeons); and on additional learning outcomes for veterinary practitioners working in the field of veterinary radiotherapy. These two tables set out the relevant knowledge, skills and competences for veterinary practitioners.

The HERCA Guidelines [4] also include tables on core learning outcomes in radiation protection for veterinary radiographers and veterinary assistants and on additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of veterinary radiotherapy. These two tables set out the relevant knowledge, skills and competences for veterinary technologists.

The HERCA Guidelines [4] note that the requirements for education and training need to be met before veterinary professionals start to work with radiation. They also note that veterinary radiographers and veterinary assistants do not have to meet all the requirements set out in them, depending on the scope of practice and the degree of autonomy that they are permitted in their State.

Veterinary practitioners (veterinary surgeons), who may also be the radiation protection officer, need to be given the responsibility for providing information, instruction and training to other staff in the veterinary facility on the risks relating to the use of radiation. These other 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. Visitors to the facility, animal owners and the public

Public exposure of persons in and around the veterinary radiation therapy facility may arise from the performance of radiation therapy. The requirements of GSR Part 3 [2] for protection of the public apply to veterinary radiation therapy facilities (see paras 3.117–3.123, 3.125–3.127 and 3.135–3.137). This section provides guidance specific to veterinary radiation therapy facilities.

Paragraph 3.78 of GSR Part 3 [2] requires all visitors, including persons delivering goods or supplies, sales personnel, accompanying persons and escorts, as well as animal owners in the facility, to be afforded the same level of protection against exposure as members of the public. Visitors to the veterinary radiation therapy facility will include animal owners accompanying animals to the facility. Such visitors may sit in a waiting room and may travel along corridors to consulting rooms. Special consideration, in all cases, needs to be given to women who are or who may be pregnant and to all persons who are under the age of 18 years.

For radiation therapy, the role of animal owners is generally limited to accompanying animals to the facility. 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 persons can receive during the period of treatment of the animals is required not to exceed the dose limits for public exposure.

The veterinary radiation therapy facility needs to have written protocols with measures for the optimization of protection and safety for owners of animals that are undergoing low dose rate brachytherapy or for owners of animals with permanent brachytherapy implants. The measures may use the three factors relevant to dose reduction ('as low as reasonably achievable') of time, distance and shielding. The written protocols may include the following:

- (a) Methods for ensuring that any dose that the animal owner receives is as low as reasonably achievable;
- (b) The values of the dose constraints that are to be applied to ensure that the dose limits for public exposure are not exceeded (see Section 2.2.3).

#### *5.4.1.1. Protection against public exposure and contamination*

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

Animals receiving brachytherapy implants may cause public exposure both in the veterinary radiation therapy facility and upon their release. The radiation protection officer of the veterinary radiation therapy facility, in consultation with the regulatory body, needs to establish rules for protection against public exposure following the release of an animal that has received brachytherapy implants. GSR Part 3 [2] requires that doses from any such public exposures be below the dose limits for public exposure and, preferably, lower than any applicable dose constraint.

Animal owners need to be provided with detailed information and written instructions concerning the precautions to be taken in order to keep exposures for themselves, their family members and other members of the public below the dose limits for public exposure. Special consideration in all cases needs to be given to women who are or who may be pregnant, and to all persons who are under 18 years of age in the animal's surroundings.

Assumptions made with regard to time and distance for the dose calculations need to be consistent with the written instructions given to animal owners at the time of release of the animals from the veterinary radiation therapy facility. Results of the calculations are to be recorded (see Ref. [75] for examples of such calculations).

The requirements of GSR Part 3 [2] indicate the necessity for arrangements to be in place at a veterinary radiation therapy facility to manage the release of animals with permanent brachytherapy implants (see paras 3.1(d), 3.2 and 3.149(b)). Once an animal that still retains one or more implanted sealed sources has been released, two groups of person need to be afforded appropriate radiation protection: members of the public who may encounter the animal; and any persons in the animal's surroundings. Furthermore, public exposure arising from a single source, such as an animal with permanent brachytherapy implants, needs to be subject to dose constraints that are set at some fraction of the dose limits.

Prior to an animal's release from a veterinary radiation therapy facility after treatment, the facility's qualified expert or radiation protection officer

needs to confirm that any dose received will not exceed the dose limits for public exposure. An acceptable method for estimating the acceptable activity of permanent brachytherapy implants for animals to be 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 owner of an animal with permanent brachytherapy implants needs to be informed that if the animal is to undergo subsequent veterinary procedures, the veterinary surgeon needs to be informed of the presence of the brachytherapy implants.

In deciding on the appropriate level of activity at the release of an animal, the licensee and the radiation protection officer need to take into account the transport and the living conditions of the animal. In some cases, such as if an owner has young children, it will be necessary to discuss precautions to be taken for radiation protection for family members. Consideration of the living conditions of the animal needs to include, for example, the extent to which the animal can be isolated from members of the owner's family. It also needs to include management of the animal's excreta and body fluids, which may contain a migrating unsealed source.

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

After the death of an animal with permanent brachytherapy implants, measures for purposes of radiation protection may be necessary for an autopsy, or for a burial or cremation. The necessary precautions need to be determined by the radiation protection officer. The determination of the necessary precautions may be made 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 concerned, and the need to minimize external exposure and the potential for contamination.

Whole body monitoring and monitoring of fingers may be necessary for personnel engaged in an autopsy of an animal with permanent brachytherapy implants, since contamination and radioactive waste are likely to be generated [76].

Precautions may also be necessary for purposes of radiation protection for the cremation or incineration of dead animals with permanent brachytherapy implants. In such cases, strict considerations of radiation protection would indicate the need to delay the release of the dead animal to the owner, or its

release for cremation or incineration, until sufficient radioactive decay had occurred. Cremation or incineration may not be permitted to be carried out, depending on the time of death of the animal and the half-life of the radionuclides concerned [75, 77].

#### *5.4.1.2. 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 local rules and procedures need to be established for access to controlled areas and supervised areas by animal owners.

Visitors are not allowed to enter treatment rooms for external beam radiation therapy or high dose rate brachytherapy, or other controlled areas, while they are in use. Exceptionally, a visitor, for example a veterinary surgeon from another facility, may be permitted to enter a controlled area or a supervised 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 veterinary radiation therapy facility needs to have written procedures specifying where and when such exceptions can be made and who may accompany the visitor. Special consideration, in all cases, needs to be given to women who are or who may be pregnant, and to all persons under the age of 18 years. Access to treatment areas for external beam radiation therapy or high dose rate brachytherapy is not permitted for any member of the public.

Controlled areas and supervised areas are required to be clearly identified to help to prevent inadvertent entry to areas where radiotherapy treatment or other radiological procedures are being performed (see paras 3.88 and 3.89 of GSR Part 3 [2], and SSG-46 [20]). Signs and warning lights, conspicuously positioned, need to be placed 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 [19]. 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.

#### **5.4.2. Monitoring and reporting of public exposure**

Requirements 30 and 32 and paras 3.127 and 3.137 of GSR Part 3 [2] establish requirements in respect of the monitoring, assessment, recording and reporting of public exposure that apply to the licensee of a veterinary radiation

therapy facility. In a veterinary radiation therapy facility, procedures are required to be in place to ensure that:

- (a) The requirements with regard to public exposure are complied with and such exposure is assessed;
- (b) Appropriate records are kept of the results of monitoring programmes.

The monitoring programme for public exposure arising from veterinary radiation therapy facilities needs to include dose assessment for exposures in the areas in and around the facility that are accessible to the public.

The dose assessment can be carried out on the basis of the shielding calculations made at the planning stage. The estimated doses can be combined with results from area monitoring at the stage of initial operation of the facility and periodically thereafter. Records of dose assessments need to be kept for a period of time that meets any relevant regulatory requirements, and in any case for a period of at least 7–10 years. The dose limits for public exposure are set out in Table 1, Section 2.2.3.

### **5.4.3. Disposal of radioactive material**

#### *5.4.3.1. 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. Recommendations and guidance on the management of radioactive waste that are applicable to radiation therapy facilities are provided in SSG-45 [29].

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  $^{60}\text{Co}$  teletherapy equipment prior to initiating the action. Depleted uranium used as shielding material is to be dealt with as radioactive waste. For example, a  $^{60}\text{Co}$  teletherapy head may contain depleted uranium and is to be dealt with as radioactive waste and managed appropriately.
- (b) The licensee needs to ensure that resources will be made available for the disposal of radioactive sources when teletherapy equipment is to be decommissioned.

#### 5.4.3.2. *Activation products*

When equipment used for radiotherapy is decommissioned, the licensee needs to ensure that activated materials from the head of the linear accelerator are properly disposed of. The regulatory body may require applicants for a licence to have in place a programme for the safe disposal of radioactive sources, or for their return to the supplier, when their use is discontinued. Such a programme would be required before authorization could be given for the import or purchase of equipment or of radioactive sources. A contract with the manufacturer or with a representative for the return of radioactive sources to the supplier is acceptable evidence of such a programme.

### 5.5. PREVENTION OF ACCIDENTS AND MITIGATION OF THEIR CONSEQUENCES

#### 5.5.1. **Safety assessment**

To comply with the requirements for safety assessment in paras 3.29–3.36 of GSR Part 3 [2], the licensee is required to conduct a safety assessment to be applied to all stages of the design and operation of the veterinary radiation therapy facility and provide for periodic review of safety. A report on the safety assessment is to be submitted to the regulatory body if so required. The safety assessment needs to deal essentially with determining ‘what could go wrong’ and how it could be prevented; and, if something does ‘go wrong’, how its consequences could be mitigated.

The safety assessment for a veterinary radiation therapy facility has to be systematic, has to identify events that could lead to potential exposure, and has to consider their likelihood and potential consequences. Paragraph 3.34 of GSR Part 3 [2] requires that the safety assessment be documented. Information on incidents, causes and contributory factors identified following reported accidents in veterinary radiation therapy facilities is given in Ref. [78], which also includes a review that considers errors of misadministration and novel challenges that arise from the adoption of advancing technologies in veterinary radiation oncology.

The safety assessment needs to cover such events and to be comprehensive. It also needs to anticipate possible events that have not previously been reported, and it should not be restricted to the consideration of incidents that have occurred. Consideration needs to be given to using systematic techniques, for example fault tree analysis, event tree analysis and techniques of probabilistic safety assessment.

The safety assessment needs to be revised: (i) when new or modified sources, including equipment, and new or renovated facilities are introduced; (ii) when operational change occurs, including changes in workload; and (iii) when operational experience or information on accidents or errors indicates that the safety assessment needs to be reviewed.

In safety assessments for veterinary radiation therapy facilities in which teletherapy or brachytherapy 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 sources;
- Use of sources in the treatment of animals;
- Care of animals with high levels of activity;
- Storage and handling of sources after removal;
- Management of unused and disused sources.

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 affect 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 in Section 5.1, unlike equipment designed and manufactured specifically for use in veterinary radiology, there is currently no radiotherapy equipment designed and manufactured specifically for veterinary use. All equipment used in veterinary radiation therapy was therefore designed and manufactured for use in medical radiation therapy.

Information on incidents, causes and contributory factors identified for reported accidents in medical radiation therapy can be found in SSG-46 [20]. Some of these scenarios could lead to potential exposure in veterinary radiation therapy.

### **5.5.2. Prevention of accidents**

Prevention of accidents is the best means of avoiding potential exposure. Paragraphs 3.39–3.42 of GSR Part 3 [2] establish requirements for good engineering practice, defence in depth and facility based arrangements to prevent accidents. Defence in depth is a hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers

placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions [3]. Design considerations for the veterinary radiation therapy facility and its equipment and ancillary equipment are described in Section 5.2.

The licensee needs to include measures for defence in depth to cope with possible events identified in the safety assessment. Measures identified in the evaluation of the reliability of the safety systems (including administrative procedures and operational procedures, and the design of the facility and of equipment) also need to be included. Information on these measures needs to be included in the education and training, maintenance and quality assurance programmes.

Operational experience and lessons identified from accidents and errors also provide valuable information. This information also needs to be included in programmes for training, maintenance and quality assurance.

The behaviour of animals and their unexpected actions can lead to accidents during radiological procedures for diagnosis and treatment. All efforts need to be made to minimize accidents involving animals, to make use of animal restraints, including measures for sedation, and to adopt practices for keeping exposures ‘as low as reasonably achievable’. In addition, animal handlers need to be appropriately trained for the responsibilities of their work. Veterinary surgeons and animal handlers need to be aware of animal behaviours that could affect radiation protection measures and that could cause incidents. Specific considerations may be necessary for the prevention of accidents in specific imaging and treatment modalities.

### **5.5.3. Mitigation of the consequences of accidents**

As stated in para. 1.20 of GSR Part 3 [2], if an event or a sequence of events that has been postulated and considered in the assessment of risks (safety assessment) does occur, it will need to be treated either as a planned exposure situation or, if an emergency has been declared, as an emergency.

On the basis of events identified in the safety assessment for the veterinary radiotherapy facility, procedures for response actions need to be prepared for possible incidents giving rise to potential exposure. These procedures need to include:

- The allocation of responsibilities and resources;
- The persons responsible for taking actions, with full contact details (contact details, e.g. for the radiation protection officer, need to be posted conspicuously throughout the facility);
- The development and adoption of procedures;

- The provision of training and periodic retraining for relevant staff in taking response 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 (see para. 3.43 of GSR Part 3 [2], and GSR Part 7 [41]).

Emergency arrangements commensurate with the hazards assessed and the potential consequences need to be established, as appropriate, in accordance with GSR Part 7 [41], GS-G-2.1 [42] and IAEA Safety Standards Series No. GSG-2, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency [79]. The emergency arrangements need to establish responsibilities and provision of resources, emergency procedures, and provision of training and periodic retraining of the relevant staff in taking the necessary response actions.

Since high doses could be received within minutes if a serious incident were to occur in a veterinary radiation therapy facility, it is important that personnel act promptly. Emergency procedures therefore need to include, for example, objectives for the speed of an emergency response, and they need to be regularly tested in exercises.

Workers involved in an incident in radiation therapy and workers engaged in emergency procedures are required to be protected against occupational exposure. Doses from occupational exposure in planned situations of exposure are required to be kept within the dose limits for occupational exposure (see Section 5.3.5). If, in an emergency, it is considered justified for the dose limits to be exceeded, however, the workers involved in the response to an incident will be considered to be emergency workers. The requirements for preparedness and response for an emergency established in paras 4.1–4.21 of GSR Part 3 [2] and in GSR Part 7 [41], and the recommendations and guidance provided in GSG-7 [24], will apply.

The radiological equipment used in radiotherapy for animals was designed for medical radiotherapy. The scenarios of incidents that have occurred in medical radiotherapy therefore need to be considered in arrangements for the management of incidents in radiotherapy and in emergency procedures for veterinary facilities using radiation therapy.

#### 5.5.3.1. *Stuck sources: General*

Response actions and emergency procedures need to be short, concise and unambiguous and, if necessary, need to be illustrated with drawings without explanatory text. The response actions and emergency procedures need to be able to be read at first sight and followed. It needs to be made clear that the term ‘first

sight' procedures refers to life saving actions or actions to be taken immediately to prevent or to limit high exposures [80]. Further actions to recover sources and to repair and test equipment before returning it to use are not of the same urgency.

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

#### 5.5.3.2. *Stuck sources: $^{60}\text{Co}$*

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

In the case of an incident, the first action is to note the time, and then immediately to use the source drive 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 put 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 radiotherapy equipment needs to be verified to ensure that it has not changed; in particular, the timer accuracy in  $^{60}\text{Co}$  teletherapy units needs to be checked.

Actions are 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 necessary maintenance, resumption of 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 its rules and regulations.
- (e) Medical attention, as necessary, needs to be provided to those involved, commensurate with the estimated doses received [41, 79].

#### 5.5.3.3. *Stuck sources: Remote control brachytherapy units*

Under the emergency plan, an emergency container needs to be kept available in the treatment room. The emergency container needs to be sufficiently large that it can accept the entire applicator assembly containing the source that has been removed from an animal and it needs to be placed close to the animal. Staff need to be trained in how to follow the procedures and need to participate in regular drills and exercises. There also needs to be an emergency kit containing long-handled forceps for manipulation of the source guide tubes and the applicators if the source fails to be returned to the safe.

In high dose rate applications, there is a need for the immediate availability of trained personnel in all applications owing to the short response time necessary for response actions (within minutes). Each of these personnel needs to be educated and trained in response actions and emergency procedures.

Manufacturers need to provide suggested emergency procedures in case the source fails to be returned to the safe. These emergency procedures generally consist of a short single page synopsis, suitable for posting in an appropriate place, of the necessary sequential steps involved in the procedure. The procedures are based on the assumption that the physical integrity of the applicator is maintained. In general, each step is based on the assumption that if the action taken fails to lead to recovery, then the subsequent action is necessary. After the necessary response actions have been taken, the following steps need to be taken:

- (a) An inspection of the machine needs to be performed.
- (b) The dose to the animal needs to be assessed and, after the necessary maintenance, resumption of 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 its rules and regulations.
- (e) Medical attention, as necessary, needs to be provided to those involved, commensurate with the estimated doses received [41, 79].

#### 5.5.3.4. *Accidents and other incidents during replacement of sources*

Only trained and authorized maintenance or service personnel may take response actions in accidents and other incidents during a change of source for external beam radiation therapy and remote control brachytherapy units. If the participation of radiation therapy personnel is necessary for any response 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. *Accidents and other incidents during transport of sources*

If the registrant or licensee has an authorization to transport radioactive material, emergency arrangements need to be in place, in compliance with the requirements of GSR Part 7 [41] and regulations and guidelines of the regulatory body.

#### 5.5.3.6. *Contamination incidents*

Following a contamination incident, the area needs to be closed to 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, respectively. The radiation protection officer needs to be contacted immediately if the possibility of contamination is suspected. Contact details for the radiation protection officer need to be posted conspicuously throughout the veterinary radiation therapy facility.

#### 5.5.3.7. *Lost sources for radiation therapy*

It is critical that the inventory of sources (see Section 5.2.2.8) is maintained and is kept up to date by the radiation protection officer of the veterinary radiation therapy facility (see para. 3.53 of GSR Part 3 [2]). It can then be determined immediately whether a source is missing. In the event of the loss of a source, it can be determined which source is missing, its type and activity, its last known location and when it was there, and who last took possession of it.

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. Immediate actions are required to be taken in accordance with GSR Part 7 [41] and GS-G-2.1 [42].

#### 5.5.3.8. *Fires, earthquakes and other external events affecting the veterinary radiation therapy facility*

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

No one, other than emergency responders, may enter or re-enter the building until it has been checked for contamination by the radiation protection officer or by the radiation safety staff of the agency in charge of emergency response. Requirements are established and recommendations and guidance on the arrangements for dealing with emergencies are provided in GSR Part 7 [41] and GS-G-2.1 [42].

## 5.6. SAFETY IN THE TRANSPORT OF RADIOACTIVE MATERIAL

Paragraph 2.25 of GSR Part 3 [2] establishes requirements on the transport of radioactive material, invoking in particular SSR-6 (Rev. 1) [17], which uses 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 to mean any package or packages, or load of radioactive material, presented by a consignor for transport [17].

The licensee of a veterinary 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 for 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 packaging and packages; test procedures; and approval and administrative requirements — are established in SSR-6 (Rev. 1) [17].

Emergency arrangements for the transport of radioactive material need to be put in place, in line with the requirements of GSR Part 7 [41] and the regulations, requirements and guidelines of the regulatory body. The licensee and the radiation protection officer of the veterinary radiation therapy facility need to be familiar with the requirements of the IAEA safety standards, and with the rules and regulations of the regulatory body. They also need to ensure that the transport of radioactive material for which they are responsible is in compliance with the requirements of GSR Part 3 [2] and GSR Part 7 [41] and with the guidance of Ref. [18] on the security of radioactive sources.



## Appendix I

### PROTECTIVE CLOTHING FOR USE IN VETERINARY DIAGNOSTIC RADIOLOGY AND INTERVENTIONAL RADIOLOGY

This appendix describes protective clothing that can be used in veterinary diagnostic radiology and interventional radiology. The radiation protection officer needs to advise the operator of the veterinary facility on the use of protective clothing, and to advise on which staff and 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) containing lead;
- Removable couch shielding made from an impervious material containing lead;
- Gloves or gauntlets made from an impervious 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 fixed at the front; a poncho 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 in the form of an apron 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 at least 0.35 mm lead if the X ray equipment operates above 100 kV. Staff in interventional radiology need to use protective clothing with at least 0.5 mm lead equivalent because of high levels of scattered radiation.

The types of gown and protective apron will depend on the radiology practice for which they will be used. It is always best to shield the largest possible area of the body. In interventional radiology, the thyroid will usually need protection. Some gowns incorporate a collar to cover the thyroid, but in most cases a separate thyroid collar will be necessary.

## I.2. SHIELDING OF THE X RAY TABLE

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

## I.3. LEAD GLOVES AND LEAD GAUNTLETS

Lead gauntlets are heavy gloves made of lead vinyl. They are difficult to use and thus have limited usefulness. Their use can increase the length of time needed for a procedure and 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 (maximum (peak) tube voltages of less than 60 kV<sub>p</sub>).

## I.4. SPECTACLES

For 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 relevant dose limit established in GSR Part 3 [2]. This dose limit is an equivalent dose to the lens of the eye of 20 mSv per year averaged over five consecutive years (100 mSv in five years) and 50 mSv in any single year. In such interventional radiological procedures, some form of eye protection is essential. One possible form of protection is glasses (spectacles) with leaded lenses and with eye protection at the sides.

## I.5. VIEWING WINDOWS

Leaded glass or leaded plastic viewing windows are common in shielding for the controlled area for X rays. The windows need to be marked with their lead equivalence and the maximum (peak) tube voltage (kV<sub>p</sub>) at which this applies.

For interventional equipment, a movable viewing window is 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 thereafter (at least every two years). If vinyl is not stored properly (storage on a coat hanger is acceptable) but is folded, for example, it will eventually crack, causing loss of shielding. Such damage may not be detected by visual inspection.

All protective lead vinyl materials can be simply tested by fluoroscopy at certain given values of maximum (peak) tube voltage  $kV_p$ . The fluoroscopy machine needs to be used in manual mode, if possible, to avoid damage to the X ray tube. Fluoroscopy screening will not measure the lead equivalence but it will reveal any deficiencies in the shielding. Faulty clothing is to be discarded immediately and not used. Each item of protective clothing will ideally be given a unique identification. Details of the purchase date and subsequent testing need to be recorded.

## Appendix II

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

#### II.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 radiation protection officer needs to be contacted immediately (contact details for the radiation protection officer need to be posted conspicuously throughout the facility) and the following actions need to be taken:

- (a) Don protective clothing and disposable gloves.
- (b) Quickly blot the spill with an absorbent pad to prevent it from spreading.
- (c) Remove the pad from the spill.
- (d) Wipe the contaminated surface with a paper tissue, wiping from the edge of the contaminated area towards its centre.
- (e) Monitor the paper tissue for residual radioactive material, for example, by using a contamination monitor or by performing a wipe test for residual activity.
- (f) Continue the cycle of cleaning and monitoring until the measurements indicate that the spill has been sufficiently removed. Try to keep the volume of contaminated waste as low as possible.
- (g) In some cases, such as with short lived radionuclides, it may be easier to quarantine the area to allow radioactive decay for a sufficient period of time. This may be done by covering the spill site, for example, 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 to be kept available at all times.
- (i) Monitor all persons involved in the spillage for contamination when they leave the room; in particular, monitor people's shoes if the spill was on the floor.

## II.2. SPILLAGE OF LARGE AMOUNTS OF RADIOACTIVE MATERIAL

After a spillage of a large amount of radioactive material — for example if an animal to which radiopharmaceuticals have been administered 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 persons not involved in the spillage from the area immediately.
- (c) Inform the radiation protection officer (contact details for the radiation protection officer need to be posted conspicuously throughout the facility) immediately of the need to directly supervise the cleanup.
- (d) Monitor all persons involved in the spillage for contamination when they leave the room; in particular, monitor people's shoes if the spill was on the floor or on the ground.
- (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 the skin occurs, wash the contaminated area of skin immediately.
- (h) If contamination of an eye occurs, flush the eye with plenty of water.
- (i) Once the contamination has been contained, follow the procedures already outlined for cleaning small spills. Particular care needs to be taken to ensure that bags of contaminated waste are appropriately labelled and stored.
- (j) Restrict entry to the contaminated area until decontamination has been completed and the area has been derestricted by the radiation protection officer.

## **Appendix III**

### **GIVING INSTRUCTIONS FOR THE RELEASE OF ANIMALS FOLLOWING ADMINISTRATION OF $^{131}\text{I}$ OR OF COMPOUNDS LABELLED WITH $^{131}\text{I}$**

#### **III.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 is preferably administered systemically as the oral form might be liable to spilling (via spitting or vomiting). The activity used depends on the veterinary indication, varying from 37 MBq (for benign thyroid disease in cats) up to 5000 MBq (for malignant thyroid carcinoma) [81].

#### **III.2. EXCRETION OF IODINE-131**

Iodine-131 (radioiodine) is excreted primarily via the kidneys and urination, and consequently urinary excretion by the animal is to be promoted by intake of water. 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. If measurements cannot be made, it is best to assume that contamination will occur via all pathways. The animal therefore needs to be confined to a restricted area in the house or the back yard on its release from the veterinary facility. It needs to be kept there away from other members of the household and away from other pets for a period as advised by the veterinary surgeon.

#### **III.3. POLICY FOR THE RELEASE OF ANIMALS**

The policy for the release of animals following the administration of  $^{131}\text{I}$  needs to comply with local statutory requirements. The decision on the release of animals following administration of  $^{131}\text{I}$  needs to take into account the circumstances of the owner of the animal and those living in the household 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 back yard. It may include the capacity of the owner to dispose properly

of contaminated absorbent material, such as material used to line the bottom of a litter box or to clean up contaminated vomit, urine and faeces.

Following the release of an animal from a veterinary practice, excretion of unbound  $^{131}\text{I}$  will continue for some time. Both contamination and external exposure to gamma radiation will therefore be a cause for concern, but both can be managed if clear instructions are provided to the animal owner.

#### III.4. ADVICE TO OWNERS ON EXTERNAL EXPOSURE

Provided that measures are taken for the containment of contamination, external exposure to gamma radiation 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 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 two 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  $^{131}\text{I}$  has effectively ceased, the external exposure to gamma radiation will decline with the effective half-life, which in the case of  $^{131}\text{I}$  is taken to be 2–3 days [82].

#### III.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 a period of time that depends on the residual activity present at release of the animal and consequent dose rates, but for at least one week. The practical steps would then need to be reviewed.

Members of the family of the owner, for example 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 kept, 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 water. Owners are to wash their hands after touching the animal. The owner needs to wear gloves when cleaning the restricted area of the house or the back yard where the animal is housed, and needs to wash hands after the cleaning has been completed.

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

### III.6. ADVICE TO OWNERS ON EMERGENCIES

In the event of illness of a treated animal that requires 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 of the therapy and the radionuclide and the activity involved. This information is to be included in the information card given to the owner on the release of the animal.

## Appendix IV

### **TYPICAL RADIATION SAFETY FEATURES FOR ROOMS USED FOR THE STORAGE, PREPARATION AND IMPLANTATION OF SEALED SOURCES FOR VETERINARY BRACHYTHERAPY**

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:

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

- (k) Hand carried transport containers with long handles need to be provided. The lid of the container needs to be securely fastened to prevent the dropping of sources on tipping of the container in transport. Containers need to bear the radiation symbol as well as a warning sign.
- (l) Space needs to be kept available for trolleys that are used for transporting sources.

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## Annex

# GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF VETERINARY PROFESSIONALS<sup>1</sup>

## 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 ionising 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 ionising 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 ionising 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 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.

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<sup>1</sup> HEADS OF THE EUROPEAN RADIOLOGICAL PROTECTION COMPETENT AUTHORITIES, Guidelines on Radiation Protection Education and Training of Veterinary Professionals, HERCA (2017). Reproduced in its entirety with permission from the Heads of the European Radiological Protection Competent Authorities. 'Should' statements are recommendations of HERCA; they are not recommendations of the IAEA.

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 formalise 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”.

## **Chapter 1: Radiation protection education and training requirements for veterinary doctors**

This chapter deals with the education and training requirements of the veterinarians, working with ionising 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 ionising 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, optimisation 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 ionising radiation.

**Table 1. Core learning outcomes in radiation protection for veterinary doctors**

Core radiation protection for all veterinary doctors			
Knowledge		Skills	Competence
on the physical interaction principles of radiation with matter (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)		(cognitive and practical)	(responsibility and autonomy)
K1. The different natural and artificial radiation sources and their relative contribution to exposure of the population	S1. Identify the legal radiation protection obligations in daily practice	C1. Implement the national radiation protection regulatory requirements in daily practice: identify flaws in implementation and correct where needed	
K2. The fundamental characteristics of radioactivity and the different radiation types emitted	S2. Apply state of the art practical radiation protection measures with emphasis on minimising exposures to staff and owners/handlers (sedation, cassette holders, ...) taking safety issues into account	C2. Take full responsibility for the justification and optimisation of procedures that require the use of ionising radiation performed by oneself or under ones' authority, both on site within the practice and in particular when ionising radiations are used off-site	
K3. The physical characteristics of X-rays and their use in imaging systems	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	C3. Take responsibility for the justification of procedures referred for more advanced imaging of therapy procedures implying the application of ionising radiation based on contemporary scientific information and indications for their use	
K4. The fundamentals of radiation detection	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	C4. Provide information to personnel and owners regarding risks and benefits of the radiographic procedures	
K5. The fundamental radiological quantities and units	S5. Estimate the dose received by non-professionals assisting in procedures and communicate about possible associated risks in particular to (possibly) pregnant women		
K6. The basics of the biological effects of radiation	S6. Communicate about specific risks of nuclear medicine procedures and the protection principles that apply		
K7. The basic principles of veterinary applications of nuclear medicine -both diagnostic and therapeutic- and the associated risks to staff and public	S7. Perform required quality assurance		
K8. The differences between deterministic and stochastic effects and their respective dose ranges for doses received by the personnel and owners	S8. Apply the protection principles of time, distance, shielding correctly		
K9. The relation between effective dose and the risk of cancer and hereditary effects			
K10. The 'linear no-threshold' (LNT) hypothesis			
K11. The general principles of radiation protection and the concepts of justification, optimisation and dose limits			
K12. The general regulations relevant to radiation protection in the veterinary sector			
K13. The regulatory requirements that apply for a practice with regard to the site, the equipment and its Quality Control, the Quality Assurance			

## Core radiation protection for all veterinary doctors

<b>Knowledge</b> <b>on the physical interaction principles of radiation with matter</b> (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
K14. The fundamentals of protection by limiting exposure time, taking distance and shielding	S9. Optimise the choice of the site and set-up when working off-site, delineate controlled/supervised area	
K15. The radiation protection aspects with respect to owners or other laypersons taking part in the radiological procedures	S10. Correctly inquire about possible pregnancy	
K16. The radiation protection aspects with respect to staff and their unborn		
K17. The principles of quality control and quality assurance with respect to radiation protection		
K18. The specific radiation protection issues of working off-site		
K19. The risks associated with transportation and handling of the X-ray device and required quality assurance		
<b>K20.</b> The phenomenon of accidental/unintended exposures and how to manage these		

**Table 2. Additional learning outcomes for veterinary doctors working in the field of nuclear medicine**

Additional radiation protection requirements for veterinary doctors working in the field of nuclear medicine			
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)	
K1. The regulatory framework governing the practice of nuclear medicine in your country	S1. For each diagnostic or therapeutic procedure, apply European and national regulations, recommendations and standards related to staff safety, owner/handler and environmental safety	C1. Take responsibility for the justification of every nuclear medicine procedure	
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	S2. Develop an organisational policy for the safe handling of unsealed radionuclides (e.g. storage, shielding, record keeping, transportation, and waste)	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	
K3. The relevant regulations concerning treatment of animals on an in-patient/out-patient basis, as well as their release criteria, where applicable	S3. Develop an organisational policy to keep doses to personnel from external and internal (inhalation, ingestion) exposure ALARA	C3. Take responsibility for optimising the administration of the radiopharmaceutical and the procedure used for a given diagnostic or therapeutic procedure based on case-specific information	
K4. The justification aspects, in particular when considering off-site procedures	S4. Apply the principles of justification (risk / benefit assessment), optimisation (ALARA) and dose limitation	C4. Develop and implement SOPs for all specialised procedures performed regularly	
K5. The basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)	S5. Decide on radiopharmaceuticals and procedures to be used	C5. Take responsibility for dealing with incidents/accidents/events	
K6. The concepts and tools for scaling administered activity depending on animal size/weight	S6. Apply the basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)	C6. Advise owners on the risks and benefits of a planned nuclear medicine procedure by using oral and written information and instructions	
K7. The principles and process steps involved in the administration of the different forms of radiopharmaceuticals applied	S7. Develop organisational policies for the optimisation of staff exposures in all specialised procedures	C7. Provide oral and/or written instructions to owners/handlers of animals that have been submitted to therapeutic nuclear medicine procedures	
K8. The actions that should be taken after misadministration and accidental/unintended contamination	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	C8. As legal person responsible for the undertaking, assume responsibility for implementing an organisational policy for protecting pregnant and breastfeeding workers from exposure risks in controlled areas	
K9. The influence of physiological and pathophysiological processes in the 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			

## Additional radiation protection requirements for veterinary doctors working in the field of nuclear medicine

Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
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	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	C9. As legal person responsible for the undertaking, assume responsibility for communicating on worker radiation protection / the organisation policy for staff protection
K12. The procedures with potentially high doses for extremities and eye lenses, such as the use of high-energy beta emitters.	S10. Estimate the total dose to the owner and/or handler	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
K13. The relevant occupational radiation protection issues associated with all specialised procedures performed, e.g. radio-synovectomy, targeted therapies with alpha or beta emitters	S11. Identify the required instructions for owners and handlers for minimising 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	

**Table 3. Additional learning outcomes for veterinary doctors working in the field of radiotherapy**

Additional radiation protection requirements for veterinary doctors working in the field of radiotherapy		
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
K1. The interaction of radiation at the molecular level and the effects of oxygen, sensitizers and protectors	S1. Apply your knowledge of clinical and radiological anatomy, physics and biology to diagnosis and therapy decision making	C1. Consult owners/handlers on radiotherapy and ensure follow up of treatment response
K2. The cellular effects, mechanisms of cell death and cell survival curves	S2. Apply treatment planning including 3D planning and virtual and CT simulation. Apply these procedures to plan animal treatments	C2. Recommend appropriate dose and fractionation schedule for curative and palliative external beam radiotherapy and brachytherapy
K3. DNA damage and the repair of radiation damage	S3. Evaluate the benefits of conformal and special radiotherapy techniques if available (IGRT, stereotactic radiotherapy)	C3. Audit an external beam radiotherapy/brachytherapy treatment plan in collaboration with physicists, radiographers and other veterinary professional and be aware of the consequences of one's actions and those of others
K4. The radiosensitivity of normal tissue systems and organs	S4. Apply algorithms for dose calculations	C4. Assess the risk of an external beam radiation therapy and brachytherapy treatment plan
K5. Tumorigenesis and leukaemogenesis	S5. Examine treatment options in the light of the prognosis	C5. Engage in planning using IMRT and other techniques such as stereotactic, particle and IGRT, if available
K6. The effect of time-dose fractionation, Linear Energy Transfer (LET), different radiation modalities and the interaction between cytotoxic therapy and radiation	S6. Develop an evidence-based treatment strategy and assess patients for curative and palliative external beam radiotherapy and brachytherapy	C6. Authorise a radiotherapy treatment
K7. The atomic and nuclear structure	S7. Analyse and synthesise research evidence to change practice	C7. Assess animals for combined modality therapy
K8. Radioactive decay	S8. Develop a radiotherapy treatment strategy and technique	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
K9. Radioisotopes	S9. Adapt treatment plans according to the animal's individual needs, pre-morbid conditions, toxicity of radiotherapy and systemic treatments	C9. Take responsibility for the clinical implications and procedures of brachytherapy using sealed and unsealed sources
K10. Radiation transport in tissues	S10. Assess and manage animals undergoing external beam radiotherapy and brachytherapy	C10. Engage in QA and follow safety policies
K11. The mechanisms of operation of the used equipment (X-ray tube, ...)	S11. Adapt course of radiotherapy treatment for individual animals according to severity of reactions, including adjustment for gaps in treatment	C11. Manage accidental/unintended exposures including notifying to the competent authority
K12. Absorbed dose		
K13. Target absorbed dose specification in external radiotherapy		
K14. Target absorbed dose specification in brachytherapy		
K15. Algorithms for 3D dose calculations		
K16. Applications of conformal radiotherapy, intensity modulated radiation therapy (IMRT), image guided radiotherapy (IGRT), stereotactic radiotherapy and particle therapy		
K17. The risk of possible side-effects (deterministic effects and secondary tumours...)		
K18. Radiation weighting factor		

Additional radiation protection requirements for veterinary doctors working in the field of radiotherapy		
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
<p>K19. Equivalent dose – tissue weighting factor</p> <p>K20. Occupational/public health consequences of radiation exposure, radiation protection and dose limits for occupational and public exposure</p> <p>K21. The management of accidental/unintended exposures</p> <p>K22. The European and national legislation Evidence based radiotherapy</p>	<p>S12. Analyse tissue reaction</p> <p>S13. Investigate accidental/unintended exposures</p>	

**Table 4. Additional learning outcomes for veterinary doctors working in the field of interventional radiology**

Additional radiation protection requirements for veterinary doctors working in the field of interventional radiology		
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
K1. The specific requirements of image acquisition and image quality aspects with respect to fluoroscopy	S1. Application of radiation physics to optimise interventional protocols, obtaining desired procedure outcome(s) while minimising exposure	C1. Choice of the best interventional equipment for your animal patient range, taking into account the resources available
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	S2. Application, on a daily basis, of all technical features and capabilities of the available equipment that allow quality-improvement and dose-reduction	C2. Provision of advice to owners/handlers on the radiation-related risks and on the expected benefits of a planned interventional procedure
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.	S3. Ability to recognise acute radiation skin effects and, where needed, adequately treat them	C3. Assumption of responsibility for justification of radiation exposure in every individual interventional radiology procedure
K4. The principle of ALARA and its applicability to interventional radiology settings	S4. Application of optimised procedure protocols by using SOPs for interventional radiology and by adapting these to the specific characteristics of the animal	C4. Assumption of responsibility for optimising the technique/protocol used for a given interventional procedure based on animal-specific characteristics and needs
K5. The meaning of justification and optimisation as applied to interventional radiology practices	S5. Choice of the best compromise between risk-benefit ratio ( image quality and procedure outcome vs radiation exposure) on a case-by-case basis	C5. Assumption of responsibility for avoiding, where feasible, very high doses to the skin, which could cause deterministic effects
K6. The concepts and tools for dose management in interventional radiology with respect to staff, members of the public and animals	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	C6. Follow-up of animals to check for the appearance of deterministic effects
K7. The factors influencing image quality and dose in interventional radiology	S7. Application of and advise on the use of radiation protection measures in interventional radiology, particularly for the hands and the eyes	C7. Assumption of responsibility for and establishment of procedures to ensure limitation of dose to staff and, where applicable, to members of the public
K8. The methods and tools for dose management in interventional radiology	S8. Recognition of cases of high skin doses which may require specific follow-up	C8. Assumption of responsibility for procurement of images of sufficient quality for the clinical purpose, while minimising staff exposure
	S9. Computational estimation of risk to staff and, where applicable, to members of the public, starting from measurement data	C9. Assumption of responsibility for conforming with radiation protection regulations

### Additional radiation protection requirements for veterinary doctors working in the field of interventional radiology

Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
<p>K9. The basic concepts exposure measurement and computational dose estimation in interventional radiology</p> <p>K10. The key considerations relevant to radiation protection when designing an interventional radiology unit</p> <p>K11. The expected doses (to staff and, where applicable, to members of the public, to reference animal for the main interventional radiology procedures</p> <p>K12. The quantitative risk and dose assessment for workers (and public, where applicable) in interventional radiology</p> <p>K13. The ability to define quality assurance in interventional radiology, to explain its management and to assign responsibilities.</p> <p>K14. The ability to list the key components of image quality and their relation to procedural staff and animal patient exposure</p> <p>K15. The regulatory framework relevant to the practice of veterinary interventional radiology in the country of practice</p>	<p>S10. Avoidance of unnecessary radiation exposure during interventional radiology procedures by optimising techniques (x-ray field size and positioning, tube-to-skin distance, beam filtration, minimisation and record-keeping of fluoroscopy time, avoidance of non-essential projections)</p> <p>S11. Development of an organisational policy to keep doses to interventional radiology staff ALARA</p> <p>S12. Able to find and apply the relevant regulations for any clinical situation in interventional radiology</p>	

## **Chapter 2: Radiation protection education and training requirements for veterinary assistants and veterinary radiographers**

This chapter deals with the education and training requirements of the veterinary radiographers and veterinary assistants, working with ionising 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 ionising 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 ionising 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 5. Core learning outcomes in radiation protection for veterinary radiographers and veterinary assistants**

Core radiation protection for all veterinary radiographers and veterinary assistants		
Knowledge on the physical interaction principles of radiation with matter (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)	Competence (responsibility and autonomy)	
	Skills (cognitive and practical)	
K1. The different natural and artificial radiation sources and their relative contribution to exposure of the population	S1. Use the appropriate medical devices in an effective, safe and efficient manner	C1. Practice effectively, accurately and safely, while taking into account guidance of legal, ethical and professional frameworks.
K2. The fundamental characteristics of radioactivity and the different radiation types emitted	S2. Identify the legal radiation protection obligations in daily practice	C2. Take responsibility for the optimisation of procedures implying the application of ionising 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)
K3. The physical characteristics of X-rays and their use in imaging systems	S3. Apply radiation protection measures in daily practice, including when accidental/unintended exposures occur	C3. Avoid unnecessary exposure and minimise necessary exposure as part of optimisation
K4. The fundamentals of radiation detection	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	C4. Carry out work in a safe manner when using ionising radiation, taking into account current safety standards, guidelines and regulations
K5. The fundamental radiological quantities and units	S5. Perform required quality assurance	C5. Participate in the process of creating and guaranteeing maximum safety for oneself, others and the animal involved, during examinations/treatments involving ionising radiation and apply the ALARA principle
K6. The basics of the biological effects of radiation	S6. Apply the protection principles of time, distance, shielding correctly	C6. Notify the responsible practitioner, if a request or referral in one's professional opinion, is dangerous or inappropriate
K7. The relation between effective dose and the risk of cancer and hereditary effects	S7. Optimise the choice of the temporary sites and set-up when working off-site, delineate controlled/supervised area, if applicable	C7. Recognise the limitations of one's own scope of competence and seek advice and guidance accordingly
K8. The 'linear no-threshold' (LNT) hypothesis	S8. Use effective, safe and efficient radiation protection methods in relation to staff, the general public and the environment applying current safety standards, legislation, guidelines and regulations	C8. Recognise the radiation hazards associated with one's work and take measures to minimise them
K9. The general principles of radiation protection and the understanding of the principles of justification, optimisation and dose limits	S9. Critically reflect on and evaluate one's own experience and practice	C9. Monitor radiation exposure with the use of a personal dosimeter
K10. The general regulation relevant to radiation protection in the veterinary sector	S10. Recognise the complicated situation pertaining to radiation protection regarding scientific knowledge	
K11. The regulatory requirements that apply for a practice with regard to the site, the equipment and its quality control, the quality assurance		
K12. The fundamentals of protection by limiting exposure time, taking distance and shielding		

## Core radiation protection for all veterinary radiographers and veterinary assistants

Knowledge on the physical interaction principles of radiation with matter (leading to imaging, shielding and biological effects) (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
<p>K13. The occupational risks to health and safety that may be encountered such as safe moving and handling of animals and equipment</p> <p>K14. The radiation protection aspects with respect to owners or other laypersons and their unborn children when taking part in the radiological procedures</p> <p>K15. The principles of quality control and quality assurance with respect to radiation protection</p> <p>K16. The specific radiation protection issues of working off-site</p> <p>K17. The risks associated with transportation and handling of the mobile X-ray device and the commensurate quality assurance requirements</p> <p>K18. The phenomenon of accidental/unintended exposures</p>	<p>on the one side and societal concern and personal emotions on the other side</p> <p>S11. Identify different image quality standards for different techniques</p> <p>S12. Apply the concepts and tools for radiation protection optimisation</p>	<p>C10. Establish safe working conditions according to the recommendations and the statutory requirements of European, national, regional legislation, where applicable</p> <p>C11. Inform and instruct other personnel, handlers, owners and persons of the public present or participating in matters relating to appropriate radiation protection practices</p> <p>C12. Place radiation risks in relation to other risks within a societal context</p> <p>C13. Reflect on one's own radiation risk perception</p> <p>C14. Evaluate the results of routine quality assurance tests</p>

**Table 6. Additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of nuclear medicine**

Additional radiation protection requirements for veterinary doctors working in the field of nuclear medicine		
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
K1. The physical principles of how radionuclides can be generated	S1. For each diagnostic or therapeutic procedure, apply European and national regulations, recommendations and standards related to staff, owner/handler and environmental safety	C1. Take responsibility for conforming to national regulations for all handling of unsealed radioactive substances.
K2. The possibilities to physically shield radionuclides	S2. Apply the principles of justification (risk / benefit assessment), optimisation (ALARA) and dose limitation	C2. Take responsibility for conforming to local standards and standard SOPs while handling unsealed radioactive substances
K3. The relevant occupational radiation protection issues associated with all specialised procedures performed	S3. Translate guidance and local rules into practical working routines so as to minimise dose to colleagues	C3. Take responsibility for the optimisation of every nuclear medicine procedure
K4. The regulatory framework governing the practice of nuclear medicine in your country	S4. Perform and interpret quality control tests to determine whether nuclear medicine equipment is within manufacturer specification	C4. Take responsibility for interpreting QC tests to determine whether nuclear medicine equipment is within manufacturer specification
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.	S5. Use devices which can be used to monitor and also minimise radiation dose	C5. Comply with good manufacturing practice when working in the radiopharmacy
K6. The relevant regulations concerning treating an animal on an in-patient/out-patient basis, as well as their release criteria, where applicable	S6. Use all relevant laboratory equipment	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
K7. The basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)	S7. Be able to work fast and clean when handling radionuclides but not at the expense of incurring an adverse event	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
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)	S8. Apply the basics of working with radiopharmaceuticals (e.g. preparation, quality control, quality assurance)	C8. Take responsibility for drawing up the correct quantity of radiopharmaceutical for administration, taking into account DRLs where applicable
K9. The radiation protection principles; legal requirements and practical solutions which can be used to enhance safe storage, handling and disposal of radioactive materials	S9. Be able to prepare, manipulate and administer radioisotopes to animals, assuring prior and post-administration radioprotection measures	
	S10. Draw up the correct quantity of radiopharmaceutical for administration	

## Additional radiation protection requirements for veterinary doctors working in the field of nuclear medicine

Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
K10. State how time, distance, shielding, monitoring and audit can be used to minimise doses received by staff and public	S11. Administer radiopharmaceuticals that are used for diagnostic procedures	C9. Take responsibility for the administration of radiopharmaceuticals which are used for diagnostic procedures
K11. The biological and physical half-lives of the radiopharmaceuticals used for diagnostic and therapeutic procedures	S12. Assist the veterinary doctor with the administration of radiopharmaceuticals used for therapeutic procedures	C10. Take responsibility for appropriate radiation protection advice to owners/handlers of animals undergoing diagnostic nuclear medicine procedures
K12. The concepts and tools for scaling administered activity depending on animal size/weight	S13. Inform and instruct the owner on the procedures and respond appropriately to questions	C11. Assume responsibility for dealing with incidents/accidents/events in a safe and efficient manner
K13. The principles and process steps involved in the administration of the different forms of radiopharmaceuticals applied	S14. Offer appropriate radiation protection advice to owners/handlers of animals undergoing diagnostic nuclear medicine procedures	C12. Contribute to advising owners on the risks and benefits of a planned nuclear medicine procedure
K14. What action should be taken after misadministration and accidental/unintended contamination	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	C13. Give instructions to owners/handlers of animals that have been submitted to nuclear medicine therapy procedures
K15. With good practice in mind, explain how a radioactive spill should be dealt with	S16. Be aware of the fact that after an administration of radioactive substances an animal should be separated from others	C14. Assist in explaining procedures to the owner and responding appropriately to their questions
K16. The influence of physiological and pathophysiological processes in the metabolism of radiopharmaceuticals from uptake to elimination	S17. Care for animals that require a high level of care whilst at the same time minimising personal radiation dose	C15. Execute the clinical workflow so that the risk of exposure to individuals (e.g. pregnant females) is minimised
K17. The nature and sources of internal and external radiation exposure for workers in nuclear medicine and for members of the public	S18. Organise clinical workflow so that radioactive animals have minimal contact with at risk individuals (e.g. pregnant females)	C16. Take responsibility for providing appropriate care for animals whilst at the same time minimising personal radiation dose
K18. Quantitatively assess dose and estimate risk for workers in nuclear medicine and for members of the public, where applicable	S19. Assess total dose to the owner and/or handler	C17. Take responsibility for performing the diagnostic procedure to a suitable standard, ensuring that no repeat examination is required because of technical deficiency.
K19. The relevant dose limits for workers (including organ doses), for pregnant workers and for members of the general public, such as owners/handlers	S20. Identify the required instructions for owners and handlers for minimising exposure (external and internal)	
K20. The procedures with potentially high doses for extremities and eye lenses, such as when using high-energy beta emitters.	S21. Deal with and/or solve incidents, accidents/events, contamination and notify the person legally responsible for the procedure	
	S22. Identify procedures that require special operational protection, e.g. extra/appropriate shielding, remote	

**Additional radiation protection requirements for veterinary doctors working in the field of nuclear medicine**

<b>Knowledge (facts, principles, theories, practices)</b>	<b>Skills (cognitive and practical)</b>	<b>Competence (responsibility and autonomy)</b>
K21. The practical measures that should be carried out to minimise dose to staff, members of the public for hybrid procedures involving X-ray CT	handling or specific dose monitoring, e.g. finger dosimeters or incorporation monitoring S23. Apply for ethical and legal approval of exposure in medical research, where applicable S24. Acquire and process images and data that have clinical relevance, observing the principles of exposure optimisation and dose management (e.g. PET/CT)	

**Table 7. Additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of radiotherapy**

Additional radiation protection requirements for veterinary doctors working in the field of radiotherapy		
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)
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 localisation and treatment planning and the treatment itself	S1. Use radiation protection methods relating to staff and the general public, taking into account current safety standards, guidelines and regulations S2. Recognise the signs and symptoms associated with treatment in different sites	C1. Work under supervision of the responsible veterinarian in a safe manner when carrying out treatments with ionising radiation, taking into account current safety standards, guidelines and regulations
K2. The principles of radiation protection underpinning radiation therapy treatments and medical imaging examinations for tumour localisation 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	S3. Identify the side effects associated with the individual treatment S4. Define the effects of concomitant treatment	C2. Assess the daily physical and behavioral status of the animal prior, during and after the treatment
K3. The principles of radiobiology underpinning radiation and cytotoxic therapy treatments, and medical imaging examinations for tumour localisation and treatment planning to include: cell biology, effects of ionising and non-ionising radiation, radiation risks, radio sensitivity, side effects of radiation therapy treatments	S5. Be familiar with reporting systems and reporting protocols managed S6. Describe the radiation hazards and how they are managed S7. Effective, safe and efficient use of positioning, immobilisation and beam shielding devices used in radiation therapy 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	C3. Record all side effects and report to the responsible veterinarian in accordance with department protocol C4. Apply safety procedures when using brachytherapy sources, if applicable C5. Engage in quality assurance and follow safety policies C6. Check, if all parameters, devices and settings are correct C7. Report incidents and near incidents to the multidisciplinary team C8. Examine any incident or near incident and how they can be prevented in the future C9. Routinely inspect the area to ensure that radiation protection measures are in place and functional
K4. The effect of time-dose fractionation, and interaction between cytotoxic therapy and radiation		
K5. The principle of Gross Target Volume (GTV), Clinical Target Volume (CTV) and Planning Target Volume (PTV)		
K6. The principle of Organs at Risk (OAR)		
K7. The different brachytherapy systems, if applicable		
K8. The principles of positioning, immobilisation and beam shielding devices used in radiation therapy		
K9. The different radiation therapy verification systems		

**Table 8. Additional learning outcomes for veterinary radiographers and veterinary assistants working in the field of interventional radiology**

Additional radiation protection requirements for veterinary doctors working in the field of interventional radiology			
Knowledge (facts, principles, theories, practices)	Skills (cognitive and practical)	Competence (responsibility and autonomy)	
K1. The specific requirements of image acquisition and image quality aspects with respect to fluoroscopy	S1. Application of radiation physics to optimise interventional protocols in collaboration with the responsible veterinarian	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	
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	S2. Application, on a daily basis, of all technical features and capabilities of the available equipment that allow quality-improvement and dose-reduction S3. Ability to recognise acute radiation skin effects S4. Application of optimised procedure protocols by using SOPs for interventional radiology and by adapting these to the specific characteristics of the animal S5. The use of personal protective equipment by interventional staff, assist in the monitoring of the workplace and individual exposure assessment, investigation S6. Application of radiation protection measures in interventional radiology, particularly for the hands and the eyes S7. Recognition of cases of high skin doses which may require specific follow-up S8. Avoidance of unnecessary radiation exposure during interventional radiology procedures by optimising techniques (x-ray field size and positioning, tube-to-skin distance, beam filtration, minimisation and record-keeping of fluoroscopy time, avoidance of non-essential projections)	C2. Participate in optimising the technique/protocol used for a given interventional procedure based on animal-specific characteristics and needs C3. Assist in avoiding, where feasible, very high doses to the skin of the animal, which could cause deterministic effects C4. Taking responsibility in avoiding high doses to their skin and eyes C5. Assist in the procurement of images of sufficient quality for the clinical purpose, while minimising staff exposure C6. Work under supervision of the responsible veterinarian in a safe manner when carrying out procedures with ionising radiation, taking into account current safety standards, guidelines and regulations	
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)			
K4. The principle of ALARA and its applicability to interventional radiology settings			
K5. The meaning of justification and optimisation as applied to interventional radiology practices			
K6. The key considerations relevant to radiation protection for an interventional radiology unit			
K7. The expected dose-ranges to staff for the main interventional radiology procedures they are assisting in			
K8. Their role within the local quality management system.			
K9. The basic regulatory framework relevant to the practice of veterinary interventional radiology in the country of practice	S9. Able to apply the relevant regulations for any clinical situation in IR interventional radiology		

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