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Radiological Protection in Veterinary Practice

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RADIOLOGICAL PROTECTION IN VETERINARY PRACTICE

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Abstract- Veterinary use of radiation in the diagnosis, management, and treatment of disease has expanded and diversified, as have the corresponding radiological protection concerns. Radiological exposure of personnel involved in veterinary procedures, and where applicable of assisting members of the public, such as owners or handlers, has always been included within the system of radiological protection. Veterinary practice is now explicitly addressed as the modern complexities associated with this practice warrant dedicated consideration, and there is a need for clarifying and strengthening the application of radiological protection principles in this area. Moreover, consistent with the pursuit of a more holistic approach in radiological protection is the consideration and integration of protection beyond humans to include the environment and the life within it. Humans share the biosphere with the flora and fauna of the environment as well as livestock, companion animals, working animals, etc. The Commission therefore now recommends that the system of radiological protection be applied in veterinary practice principally for the protection of humans but also with explicit attention to the protection of the exposed animals. Additionally, consideration should be given to the risk of potential contamination of the environment associated with applications of nuclear medicine in veterinary practice. This report focuses primarily on justification and optimisation in veterinary practice along with the underlying ethical values, and it sets the scene for more detailed guidance to follow in the future recommendations. It is intended for a wide-ranging audience, including radiological protection professionals, veterinary staff, students, education and training providers, and members of the public as an introduction to the issues surrounding radiological protection in veterinary practice.

Keywords: veterinary practice; animal patient; justification; optimisation; ethics

MAIN POINTS

- **The objective of this publication is to provide an initial set of relevant observations, considerations, and general recommendations related to radiological protection in veterinary practice and is intended for a wide-ranging audience as an introduction to the related issues.**

- **Radiological protection challenges specific to veterinary practice arise from the different combinations of personnel and members of the public that may be involved and from operational environments required when dealing with animals.**

- **The priority of radiological protection in veterinary practice is that of the humans involved, but the animal's exposure should also be the object of explicit attention because like humans, animals are subject to potential tissue reactions or stochastic effects resulting from exposure to radiation.**

- **In veterinary practice, the core ethical values of the system of radiological protection are complemented with correlated ethical values such as respect for life and animal welfare, and the values of empathy and stewardship are needed in the implementation of the system of protection in veterinary practice and in its application to animals in general.**

- **Veterinary applications of ionising radiation, and their ensuing protection challenges, are to a large extent comparable to medical and non-medical human exposure situations and could benefit from similar approaches, such as the three levels of justification, and optimisation as a process for ensuring that the likelihood and magnitude of exposures and the number of individuals exposed are reasonable and appropriate for the situation at hand, considering economic, societal, animal welfare, and environmental factors.**

1. WHY THIS PUBLICATION?

(1) Why this publication on radiological protection in veterinary practice? Modern medical imaging techniques often have a pivotal role to play in the diagnosis of injury and disease in animals and have therefore become an essential tool in the provision of high-quality veterinary care. The same holds true in providing the best possible advice to owners, breeders or potential purchasers on the suitability of an animal for a specific purpose. On the treatment side, different radiotherapy modalities, including nuclear medicine techniques, are now increasingly available and will contribute to providing the quality-of-care owners want for their beloved animals.

(2) Factors such as the digitalisation of radiology, the large availability of second-hand equipment from human medicine and the manufacturing of dedicated veterinary equipment have made radiological procedures more widely attainable. Under the rising pressure of public demand, the number of radiological procedures has therefore substantially increased in recent years.

(3) Although this evolution can be applauded from the veterinary services side, practitioners need to be more than ever aware of the radiation risks present. Indeed, digitalisation of imaging is not just increasing the mean number of procedures, it may also increase the mean number of views per procedure as it may come with an increase of radiation dose per view. Practitioners need to be aware that the radiation dose from a CT, from a nuclear medicine diagnostic procedure or from a fluoroscopically guided intervention can be substantially higher than the one encountered in standard radiologic imaging.

(4) Radiological risks have increased in veterinary practice as a result of these evolutions, and they can affect both the animals examined or treated as well as the humans assisting in these procedures—professionals and members of the public alike. When working with radioactive materials in applications such as nuclear medicine, persons not actually present during the procedures could also be exposed or become radioactively contaminated, as could the environment, for example as a consequence of inadequate management of waste (urine, faeces) passed by an animal following a nuclear medicine procedure.

(5) The objective of the current publication is not to discourage veterinarians or animal owners from the beneficial uses of ionising radiation in veterinary practice. Far from it, the benefits of radiological techniques in veterinary practice are more than convincing; such techniques enable the provision of the best possible animal care as well as solid advice to owners, breeders, and purchasers. But the Commission insists on including radiation protection considerations in clinical practice so that procedures can be done safely from that perspective also.

(6) The implementation of radiological protection measures does not need to be overly complex or difficult. Although some of the terminology may be unfamiliar at first, such measures are consistent with other approaches to workplace and patient safety. The approach to radiation protection is completely in line with what can be expected from other aspects of day-to-day quality veterinary services. The first principle of radiation protection for instance, that of 'justification' transposes the 'primum non nocere' or first do not harm concept of the Hippocratic Oath: it tells us to only perform radiological procedures that are appropriate in the context at hand, therefore to refrain from superfluous ones. The second principle, that of 'optimisation', tells us to adapt the procedural settings in such a way that the diagnostic or therapeutic objective is met while optimising protection and safety, therefore with a radiation dose to the animal itself and to humans involved which is as low as reasonably achievable. Just as one would adapt the dose of a pharmaceutical product to the animal's weight. In standard radiology for instance, strictly limiting

the exposure zone to the region of clinical interest will lead to better image quality for a lower dose. In interventional procedures, on top of restricting the radiation beam to the region of interest, the skilful use of pulsed fluoroscopy mode can make a tremendous difference.

(7) But unfortunately, working correctly and safely with complex techniques and advanced equipment is not always that simple. For such applications, in particular the therapeutic ones, additional—and continued—education and training efforts are undoubtedly required.

(8) Finally, the constant and safe provision of quality diagnostic and therapeutic services when using ionising radiation demands that radiation protection considerations be integrated in the quality management of the undertaking, be it a small one-person private practice or a big veterinary hospital. This quality system should oversee the facility and its dedicated rooms, the equipment and their quality control, the qualifications of staff and their ongoing education and training, the procedural rules, the records which should include dose indicators, the incident and accident management, etc.

2. INTRODUCTION

2.1. Objective

(9) Veterinary practice has changed considerably over the last few decades, and along with it, the number of applications using ionising radiation has increased in type and variety. More specifically, such applications have greatly diversified to now comprise interventional radiology and CT scanning, nuclear medicine applications including unsealed source therapy and mixed modality imaging, as well as brachy- and tele-therapy (Johnson, 2013; LaRue and Custis, 2014; Kent et al., 2018; Scansen and Drees, 2020) with a wide variety of animals beyond cats, dogs, and horses being treated (e.g. Adkesson and Ivančić, 2019; Schilliger et al., 2020). The potential risks associated with radiation exposure have increased and diversified accordingly, with potential impact on veterinary staff, members of the public including animal owners and handlers, the environment, and the exposed animals. This publication seeks to draw attention to these radiological protection challenges and how they can be managed by applying the International Commission on Radiological Protection's (ICRP) framework. It is intended for a wide-ranging audience, including radiological protection professionals, veterinary staff, students, education and training providers, and members of the public as an introduction to the issues surrounding radiological protection in veterinary practice.

2.2. Scope and Context

(10) Radiological protection in the field of human medicine has been the subject of many ICRP publications, both at a general level (ICRP, 2007b) and in relation to specific aspects of it (e.g. ICRP, 2013a,b, 2014, 2018). These publications may provide inspiration for developing specific guidance and advice that can be applied in veterinary practice, keeping in mind that although veterinary practice has many similarities to human medicine in terms of radiological protection considerations, it also has many differences. Both practices involve the need to protect professional workers, who may or may not be classified as being employed in relation to occupational radiological protection, plus the need to protect the general public and the environment, and of course to protect the patient. In the case of veterinary practice, though, the patient is an animal.

(11) The protection of humans in veterinary practice raises a number of challenges because of the different combinations of personnel involved, and the different operational environments required when dealing with animals. The exposure of the animal also raises specific issues, as individual animals have not previously been considered within the context of the system of radiological protection. Following on from the latest extension of the ICRP's mandate beyond that of the protection of humans to one that encompasses the protection of non-human species (i.e. biota) in an environmental context (ICRP, 2003b), the Commission has now determined, through detailed consideration of protection of the animal in many aspects of veterinary practice and based on a report from a Task Group set up to examine the issue, that it is both appropriate and timely to include consideration of exposed animals in its recommendations (Pentreath et al., 2020). The first step, as set out in this current report, is that of considering how this subject may be accommodated within the existing overall framework of radiological protection.

(12) The ICRP has always acknowledged that its guidance with regard to all medical practices has necessarily been somewhat different from that relating to other categories of radiation exposure. Thus, for example, human patients are exceptions from the principle of dose limits because generic dose limits might reduce the effectiveness of the diagnosis or treatment, thereby doing more harm than good. Emphasis is therefore placed on the justification of the procedures in the first place, on the optimisation of protection in relation to the source and, for diagnostic procedures, on the use of diagnostic reference levels. Even the justification principle in the radiological protection of human patients is somewhat different from other human exposure situations in that, generally, both the benefits and the risk relate uniquely to the same person (although other aspects may apply – such as doses to medical staff). Also, any specific method or procedure that can be regarded as justified in general does not necessarily imply that its application to a specific patient is in itself fully justified.

(13) In the case of veterinary practice, fundamental issues also arise with regard to the principles of justification and optimisation, and these inevitably spill over into morals and ethics relating to the exposed animal's health and well-being. This report therefore dwells upon these topics – ethics, justification, and optimisation in veterinary practice – at some length, and sets the scene for more detailed guidance to follow in the future.

2.3. Background and motivation

(14) After Röntgen's discovery of x-rays, veterinarians were amongst the first to perceive the potential benefits of radiology for animal health care (Beamer, 1939; Schnelle, 1968; Kealy, 2002). In January 1896, post-mortem animal radiographs [fish, frogs, a snake, a lizard, a rabbit, a chameleon (Fig. 2.1, left), and a rat (Fig. 2.1, right), as photogravures] were published, with the first veterinary radiograph of an equine foot published in March of the same year (Eder and Valenta, 1896; Johnson, 2013). Diagnostic radiography (or 'Roentgenology') was widely used by military medical departments by World War I, including in veterinary medicine (Fig. 2.2).

(15) Starting with the rise of small animal practice in the 1930s, plain film radiography (Figs 1.3 and 1.4) was about the only veterinary application of ionising radiation for many decades. Moreover, the number of procedures was limited and the doses to human bystanders low to trivial, provided that some simple rules were followed (Wantz and Frick, 1937). Consequently, veterinary use of ionising radiation was not a high priority for veterinarians or radiological protection professionals (Wood et al., 1974), although there were some relevant publications that provided guidance or otherwise stressed the importance of radiological protection in veterinary practice (e.g. NCRP, 1970; NHMRC, 1982, 1984; NEB, 1989). Even just over 15 years ago, the prevalence of veterinary radiology was acknowledged to be low (NCRP, 2004). However, since then veterinary procedures making use of ionising radiation have substantially increased and are now as diverse as in human health care, although not necessarily universally available (Johnson, 2013; LaRue and Custis, 2014).

(16) Veterinary diagnostic radiology has become more popular for a few reasons, including digitalisation and the wider availability of sophisticated- and higher dose-applications such as computed tomography (CT) and cone beam computed tomography (CBCT) scanning throughout the world (McEvoy, 2015). Digitalisation, which enables images to be processed, stored, and shared electronically, has made radiologic imaging much more convenient compared to traditional film-screen radiography. Images can be viewed immediately, and digital detectors enable images

to be interpretable over a wide range of exposure parameters. Although this feature diminishes the need for retakes, the ease of the digital imaging process often leads to an increase in the mean number of exposures per study. At the same time, there will be a tendency to choose exposure parameters at the high end of what is compatible with interpretable images, often referred to as exposure creep (Gibson and Davidson, 2012). Both these tendencies will result in higher doses to the animal and to all human bystanders. Interventional radiology procedures have entered the practice field, and so have nuclear medicine applications, both diagnostic and therapeutic. Lastly, brachytherapy and external beam radiotherapy have become available in multiple centres around the world, although there are great differences in local availability.

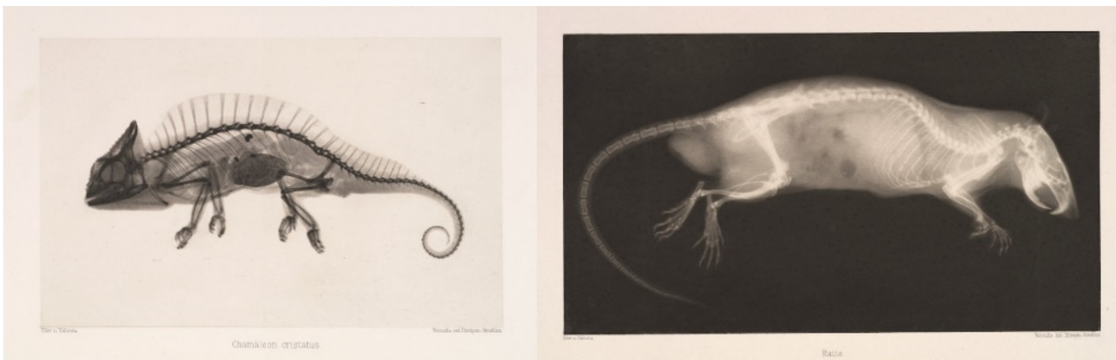

Fig. 2.1. ‘Chamäleon cristatus’, Plate 8 (left) and ‘Ratte’, Plate 13 (right), J.M. Eder and E. Valenta, Photogravure of x-rays (1896) Versuche über Photographie mittelst der Röntgen'schen Strahlen, The Metropolitan Museum. https://www.metmuseum.org/art/collection/search/660046

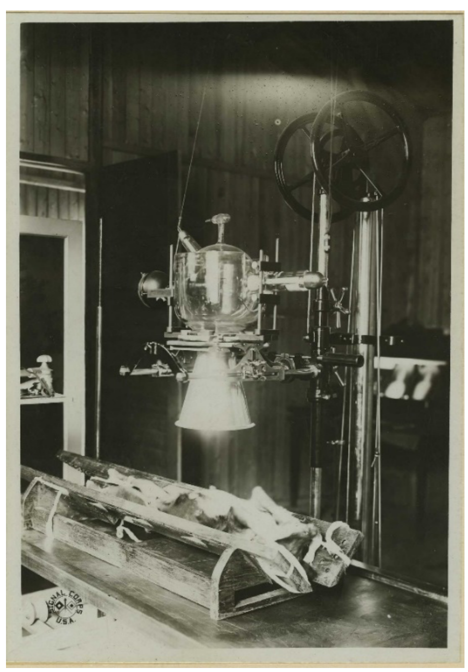

Fig. 2.2. Operating upon a dog, for instruction, at Central Medical Department Laboratory, Dijon, France, September 6, 1918 (Reeve 10216). OHA 80 Reeve Photograph Collection. Courtesy of Otis Historical Archives, National Museum of Health and Medicine.

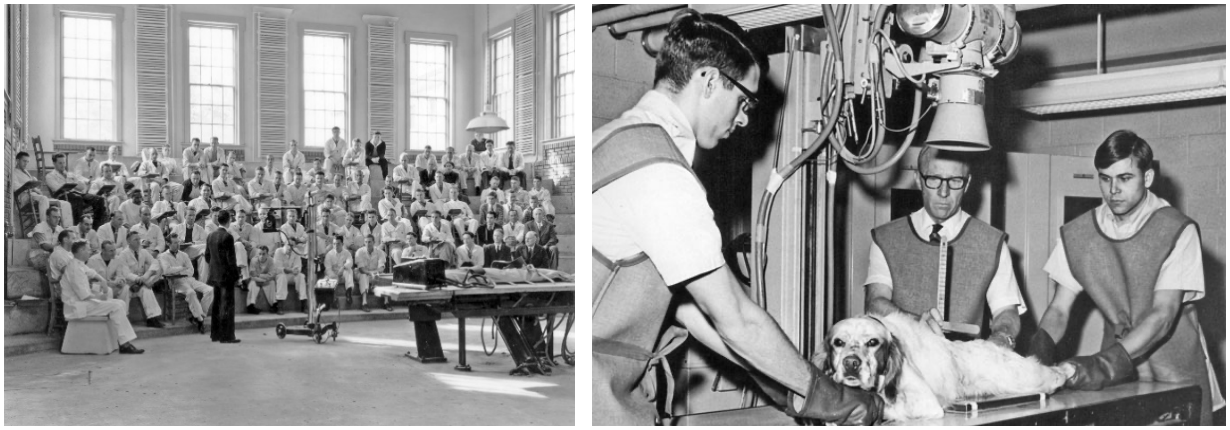

Fig. 2.3. Veterinary lecture on radiography, 1936 (left); Students x-raying a dog, 1969 (right) both at Kansas State University (KSU), Manhattan, Kansas, United States. Courtesy of College of Veterinary Medicine at KSU.

Fig. 2.4. (Left) Veterinary students and their professor preparing to x-ray a dog, College of Veterinary Medicine, University of Minnesota, St. Paul, Minnesota (~1965). Courtesy Minnesota Veterinary Historical Museum. https://reflections.mndigital.org/catalog/p16022coll525:6 (Right) Radiologist examining a horse with modern X-ray equipment at the Veterinary Sciences College, Massey University, 1969. The photo is from Archives New Zealand's National Publicity Studios collection; R. Anderson (photographer); licensed under CC BY 2.0.

(17) Radiation-related risks have also expanded because of these important practice changes. For example, in addition to the external exposure associated with nuclear medicine procedures, relevant veterinary clinics also need to consider the risk of contamination by radioactive substances to staff, owners, handlers, and to the environment. Lessons learned from human medicine inform us that radiation exposure of veterinary staff involved in interventional procedures also needs to be closely monitored since doses could be significant (e.g. Klein et al., 2009; Duran et al., 2013; Ko et al., 2018), as could the doses to the animal patients themselves (e.g. Wagner, 2007; Balter and Miller, 2014; Arkans et al., 2017). Moreover, unique issues associated with animal patients may result in higher occupational doses associated with certain procedures. For example, it has been shown that veterinary positron emission tomography (PET) procedures often result in higher doses

to staff than comparative PET procedures with human patients. This increase in dose is associated with the need for additional care associated with animal anaesthesia, which is necessary in a number of radiological procedures to ease patient handling and positioning as well as to reduce motion artefacts (Martinez et al., 2012).

(18) Societal changes also play a role in the increasing number and diversity of procedures performed on animals. Many companion animals are considered by their owners as ‘part of the family’, and therefore entitled to the best care available. The same may hold true for working animals, endangered species, exotic and sports animals, also when their monetary value may further stimulate owner interest in their animals’ welfare. More and more, owners make sure that their animals are covered by specific health insurance (NAPHIA, 2020), which may require radiological exams as part of insurability checks, and also removes financial barriers that would otherwise restrict the use of these more expensive imaging or treatment options (Kippermanet al., 2017). The imaging of animals now also has a prominent place in a wide variety of suitability checks, such as suitability for breeding or for a career in sports. These procedures, which may not primarily be performed for the benefit of the animal exposed, can become a radiological protection challenge in terms of the high number of exposures and the fact that a limited number of staff and members of the public may be involved in many procedures.

(19) The impact of these changes in veterinary practice on the radiological protection needs and challenges have not gone unnoticed, and some authorities and organisations have produced guidance accordingly. For example, the National Council on Radiation Protection and Measurements revised the relevant 1970 report in 2004, and succinctly summarised the goal of radiological protection in veterinary medicine (NCRP 2004):

The reasons for using radiation in veterinary medicine are to either obtain optimum diagnostic information or to achieve a specific therapeutic effect while maintaining the radiation dose to the radiological personnel and the general public as low as reasonably achievable (the ALARA principle). Similarly, it is also important to avoid all unnecessary irradiation of the animal patient.

(20) The Radiological Protection Institute of Ireland (RPII) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) also both published relevant guidance in the 2002 ‘Code of Practice for Radiation Protection in Veterinary Medicine’, and the 2009 ‘Code of Practice & Safety Guide for Radiation Protection in Veterinary Medicine’, respectively, each an update of similar reports from the 1980s (RPII, 2002; ARPANSA, 2009). More recently, the International Atomic Energy Agency (IAEA) has prepared a Safety Guide related to radiological protection and safety in veterinary medicine (IAEA, 2021), and various activities have been developed by a dedicated working group within the Heads of the European Radiological Protection Competent Authorities (HERCA), a voluntary organisation of Europe’s radiological protection regulatory authorities (HERCA, 2012).

(21) The ICRP, now recognising that the complexities of veterinary practice warrant dedicated clarification within the system of radiological protection, has decided that there is a need for strengthening the application of its protection principles in this area (Martinez and Van Bladel, 2020). As mentioned above, the objective of the current publication is not to provide direct, practice-oriented advice, but rather an initial set of relevant recommendations and considerations. Its primary focus will be the protection of humans involved in or affected by the procedures, both professionals and members of the public. The animal patient’s protection is also considered as well as protection of the environment from nuclear medicine applications.

3. BASIC CONCEPTS OF RADIOLOGICAL PROTECTION

3.1. Dosimetric Quantities

(22) Quantities and units used in the system of radiological protection are covered in Annex B of the 2007 Recommendations of the ICRP (ICRP, 2007a) as well as the online ICRP Glossary (http://icrpaedia.org/ICRP_Glossary). It should be pointed out, however, that most of these quantities and units have been exclusively developed to fit the protection of humans exposed to ionising radiation.

(23) *Absorbed dose* is the energy imparted by ionising radiation to a mass, per unit mass, and has units of J kg^{-1} with the special name gray (Gy). Absorbed dose, which can be measured, is the fundamental physical quantity used in radiological protection as it can be reasonably related to radiation effects, particularly those associated with tissue reactions in people. Absorbed dose is the most appropriate dosimetric quantity for use in setting limits on organ/tissue doses to prevent tissue reactions (i.e. deterministic effects, see section 3.2.1) in people, and it is currently the only appropriate dosimetric quantity for expressing doses to animals (ICRP, 2014, 2021b).

(24) *Equivalent dose* is derived from absorbed dose by accounting for biological effectiveness, or *quality*, of the different types of radiation (e.g. alpha, beta, gamma) and generally applies to a specific human organ or tissue. Note that the Commission expects to change from the use of equivalent dose to absorbed dose in setting limits on organ/tissue doses for people at the time that new general recommendations are issued (ICRP, 2021b). Equivalent dose serves, then, as an intermediate step in the calculation of *effective dose,* which is an additionally weighted quantity that accounts for different tissue radiation sensitivities with respect to the induction of stochastic effects and applies to the whole (human) body (ICRP, 2021b). Effective dose is a risk-adjusted quantity that enables consolidation of doses received from all radiation types and from internal and external exposures for the purpose of managing protection of people at low to moderate doses; it is of particular use in the optimisation of protection for workers and members of the public. Effective dose may be considered as an approximate indicator of possible risk in a population of people, recognising that lifetime cancer risks vary with age at exposure, sex, and population group (Harrison et al., 2016; ICRP, 2021b). Equivalent and effective dose have the same SI units as absorbed dose, J kg^{-1}, but are expressed using the special name sievert (Sv). Of note is that these quantities were developed utilising methodology and models specific to humans.

(25) *Activity* refers to the amount of radioactive material present and is typically expressed as the number of nuclear transformations (or disintegrations) per second with the unit becquerel (Bq), which is equivalent to s^{-1}. Dose coefficients have been developed for humans to estimate the radiation dose associated with an exposure to a given quantity or concentration of a radioactive substance and are often expressed as Sv Bq^{-1} (ICRP, 2012a, 2020a).

(26) Because the radiation sensitivity of animals is known to differ from one species to another and even between different breeds of the same species, current radiation and tissue weighting factors (and thus equivalent and effective dose) cannot be used as such to estimate exposure and ultimately radiation-induced risk incurred by an animal submitted to a procedure in which ionising radiation is used. It should therefore be emphasised that radiation doses for any animal can only be expressed in terms of absorbed dose (Gy). However, recommendations have recently been made for weighting absorbed dose based on radiation quality for (non-human) biota in an environmental

context (ICRP, 2021a). Note that twelve ICRP Reference Animals and Plants (RAPs) for relating exposure to dose and dose to biological effect have been described at the taxonomic level of family, two of which are for big and small mammals: *Cervidae* (deer) and *Muridae* (rodent). These RAPs are intended to be broadly representative of environmental biota. Dose coefficients for RAPs are formulated in terms of absorbed dose rate (μGy d^{-1}) per unit activity concentration (Bq kg^{-1}) to which the organism is exposed (ICRP, 2017b). In the development of these dose coefficients, data on biological effects relating to external and internal sources of radiation were drawn from a wide range of relevant literature (ICRP, 2008), which, although not specifically focused on veterinary applications, does provide a useful baseline for information on radiation effects in animals.

(27) Although a full suite of veterinary dose coefficients does not exist, some limited experimental research has been done in this area (e.g. Hall, 2011), and in addition there are a variety of computational anatomical animal models available that are suitable for dosimetric modelling (Zaidi, 2018), including at least five for canines (Padilla et al., 2008; Kramer et al., 2012; Stabin et al., 2015), and many databases exist on the effects of radiation on mammals (e.g. Zander et al., 2019). A discussion of currently available dosimetric data in veterinary diagnostic radiology is included in section 6.2.2.

3.2. Summary of biological basis for radiological protection

(28) Adverse biological effects induced by radiation may be divided into two main categories: tissue reactions leading to tissue/organ damage (also called deterministic effects), and cancer and heritable diseases (also called stochastic effects) (ICRP, 2020b). These effects are briefly summarised here; the biological basis for radiological protection is covered thoroughly in Annex A of the 2007 Recommendations (ICRP, 2007a) and other Commission documents (ICRP, 2003a, 2012b).

(29) Our current knowledge about the detrimental effects of radiation has been developed from a series of sources, to which experiments on animals have significantly contributed. Animal models are frequently used to extrapolate health risk, carcinogenic or otherwise, to humans (Davidson et al., 1986; Fjeld et al., 2007). For these reasons, although not specific to the practice of veterinary medicine, there is a good amount of data on the effects of animal exposure to a variety of radiation types, albeit predominantly at high doses or dose rates. Although large radiobiology studies often focus on murine models, animal species of broader interest in veterinary medicine, such as canines, have been studied as well (see, for example, ICRP, 2008; UNSCEAR, 2010; Haley et al., 2011; Singh et al., 2015; Tang et al., 2017). Effects observed in exposed animals are of the same nature as those seen in humans, although the dose-effect relationships may be different (NRC, 1991). Exposure of animals (companion, livestock, wild animals) to clinically significant doses of ionising radiation similarly results in adverse biological effects as in humans, but to a variable extent (von Zallinger and Tempel, 1998; Fesenko, 2019). Radiation effects vary amongst species, breed/strain (genetic susceptibility and individual radiosensitivity), sex, age at exposure, dose (cumulative) and dose-rate as well as radiation quality and mode of exposure (external or internal) (Misdorp, 1996).

3.2.1. Tissue reactions (deterministic effects)

(30) Tissue reactions result after exposure to high doses of radiation over a relatively short period of time and manifest clinically when the radiation dose received is above a given threshold.

These effects are seen in companion animals treated with ionising radiation for therapy (e.g. cancer, pain alleviation). Although originally defined as such for humans, effects are often classified as acute (manifesting shortly after exposure) or late (manifesting months to years after exposure) in animals as well (Collen and Mayer, 2006; ICRP, 2012b). As in humans, as the dose increases, the effect is seen with increasing frequency and severity, and specific effects depend on the tissue irradiated (e.g. LaDue and Klein, 2001).

(31) In radiotherapy, high radiation doses delivered to the target tissue induce tissue reactions that ultimately prevent cancerous cells from further out-of-control multiplication. That said, effects such as skin burns and ocular effects are potential undesired effects on healthy tissues in some therapeutic procedures and cannot always be avoided (Gillette et al., 1995; Collen and Mayer, 2006; Pinard et al., 2012). For example, in interventional procedures, lesions such as radiation induced skin burns in the area where the primary radiation beam enters the body may appear within weeks, particularly when complex procedures requiring prolonged fluoroscopy times are performed on larger animals. Most such injuries can be managed and are self-limiting, but it is important to remember that unnecessary tissue reactions result in needless suffering; overexposure in radiotherapy can result in excessive and severe tissue reactions that are very painful and can also lead to a variety of long-term complications. The specific complication will depend on the technology being used, dose fraction and total dose, as well as the organ at risk in the target volume. These delayed complications can be benign or more severe and tend to be irreversible (e.g. fibrosis, necrosis, chronic inflammation) and difficult to treat, with detrimental impact to the patient's quality of life in both animals and people (Gillette et al., 1995; Collen and Mayer, 2006; Balter and Miller, 2014; Hall and Giaccia, 2019). Tissue reactions may also appear as a result of prenatal exposure, discussed further in section 3.2.3.

(32) Although occupational doses received in veterinary practice are generally too low to observe tissue reactions, some nuclear medicine procedures, interventional or brachytherapy procedures, combined with poor practice, incidents, or accidents, have the potential to result in skin burns or lens of the eye effects, based on experience in human medicine (Miller et al., 2010; Dauer, 2014; ICRP, 2018b).

3.2.2. Stochastic effects (cancer and heritable effects)

(33) Stochastic effects are those effects for which the probability of occurrence, but not severity, is a function of dose with no apparent threshold. Ionising radiation can interact with a cell such that the cell is damaged, but can continue through the cell cycle, thus potentially leading to a malignant disease. Stochastic effects resulting from exposure to ionising radiation include cancers, which can result from damage to somatic cells, and heritable effects, which can result from damage to germ cells. Of note is that a wide variety of environmental contaminants as well as naturally occurring mutations in somatic and germ cells also contribute respectively to cancers and hereditary diseases (NRC, 2006; Fjeld et al., 2007).

(34) Although there are indications of an increase in cancer risk for exposed children—including after in utero exposures—in the range of 50-100 mSv (Wakeford and Bithell, 2021), an elevation of cancer risk in exposed members of the public at doses below about 100 mSv cannot be firmly demonstrated by epidemiological surveys alone. However, seen in combination with a deliberately prudent interpretation of radiation physics and radiation biology data, the Commission recommends that a linear no threshold model be used for the purpose of applying its system of radiation protection in risk management. This model assumes a linear relationship between dose

and stochastic risk, which means that any increase in dose may result in an increase in the stochastic risk, bearing in mind that risks are increasingly uncertain at lower doses (ICRP, 2021b). It is challenging to develop definitive risk predictions for radiogenic disease at low doses because there are a variety of factors that contribute to overall risk as well as additional modifying factors that can influence the promotion or progression of the disease (NRC, 2006; McLean et al., 2017). The risk indicator used by the Commission for humans is the radiation *detriment* which is sex- and age-averaged over a composite reference population. It is determined from the lifetime risk of cancer and considers severity in terms of lethality, quality of life, and years of life lost. It also considers heritable effects based on information from animal studies (ICRP, 2007a, 202X).

(35) With respect to exposed animals, a common misconception is that an animal with a short lifespan compared to a human will not experience radiogenic cancer. However, it has been widely observed since the 1970s that, across species, neither an increased body size nor longer lifespan is associated with an increase in carcinogenesis risk as theoretically expected from the associated increase in number of cells or cellular divisions, respectively (Abegglen et al., 2015). This provided foundational insight for the modern recognition that the physiological factors influencing organisms' responses to carcinogens are varied and complex.

(36) Cancer patterns in mammals are similar, and in general, relative to life span (Albert et al., 1994; Schiffman and Breen, 2015), or in other words, *risk of cancer in old age is not vastly different in species with very different life-spans* (Peto, 2016). Latency periods are less than that in humans for many animals with shorter, physiologically compressed lifespans (NRC, 1991; Backer et al., 2001). Of interest to veterinary practice is the observation that dogs, as compared to other species studied, demonstrate a greater risk of developing cancer as a result of exposure to ionising radiation, and for cancer prevention in dogs it has even been explicitly stated in the literature that *dogs should be exposed to radiation only when the expected benefits will outweigh the risks* (Kelsey et al., 1998), consistent with the principle of justification in radiological protection.

(37) Inheritance of radiation-induced abnormalities was reported by Hermann Muller in 1927 based on studies with x-ray irradiation of *Drosophila* (fruit flies) (Pontecorvo, 1968). Radiation exposure can only increase the incidence of the same mutations that occur spontaneously in a population (Hall and Giaccia, 2019). This makes potential heritable radiogenic effects in humans difficult to study because of the high natural incidence of the same mutations. Thus, hereditary effects in humans have not been definitively or reliably shown to be induced by ionising radiation exposure (Boice, 2020; NCRP, 2021), despite ample evidence of radiogenic hereditary effects in plants and animals (e.g. Russell, 2013). Humans are likely also susceptible to these effects, but with risk much lower than that for carcinogenesis (UNSCEAR, 2001, 2014).

(38) In humans, the likelihood of developing cancer in response to exposure to a carcinogenic agent depends on a variety of factors including, but not limited to, age; sex; environmental, socioeconomic, and lifestyle factors; and genotype (Colditz GA et al., 1996). Individual variability in radiosensitivity to carcinogenesis is acknowledged, but not fully understood (Rajaraman et al., 2018). However, there are some clear, population-level attributes, such as age and sex, that influence susceptibility to radiation-induced carcinogenesis (NRC, 2006; Preston et al., 2007). This risk is overall higher for the fetus, children, and adolescents, due to longer life ahead and the comparative sensitivity of developing organs and tissues (ICRP, 2013b), and for females, primarily due to the radiosensitivity of the breast (Boice et al., 1991; NRC, 2006). This age- and sex-dependence of risk should be considered in the process of justification and optimisation, particularly with respect to children. For example, in veterinary practice, children and young

adolescents are excluded from assisting in radiological examinations as the exposure is not justified. Similarly, the potential presence of individuals who are or may be pregnant needs careful consideration with respect to justification when radiological procedures are being performed; this has to do with both the radiosensitivity of the unborn child (section 3.2.3) and the possible particular sensitivity of the breast tissue in some stages of its preparing for lactation. The justification process for any such exposure should bear in mind that the dose limit for the unborn child (1 mSv during the pregnancy) is not to be exceeded. If the presence of the pregnant or possibly pregnant individual is deemed justified, and informed consent is given, then the exposure needs to be optimised. This could be achieved by providing instructions on where to stand, how to behave, what protective equipment to use, etc. Strategies for optimisation are discussed further in Chapter 6.

(39) It has been similarly shown in laboratory animals that age at exposure and sex influence the risk of carcinogenesis, although to a varying extent (Benjamin et al., 1991; Shuryak et al., 2010; Haley et al., 2011; Tang et al., 2017). These risk dependencies are thus also relevant considerations for animal patients, as some groups receive exposures from a young age (e.g. dysplasia screening in puppies) (Dziuk, 2007) or presale examinations of performance horses (Judy, 2013). Being mindful of these risks is especially important when determining if non-medical exposures are justified (discussed further in section 6.2).

3.2.3. Effects of in-utero exposure

(40) Radiation effects on the embryo/fetus during pregnancy (i.e. teratogenic effects) depend on the stage of pregnancy at the time of exposure, the absorbed dose to the embryo/fetus and radiation type. At most diagnostic levels, effects include risk of childhood cancer, while at doses in excess of 100-200 mGy during the most radiosensitive fetal time period, there are risks of deterministic effects including nervous system abnormalities, malformations, growth retardation, intellectual disabilities, and fetal death (ICRP, 2000, 2003a). *Publication 84* (ICRP, 2000) discusses the management of pregnant patients and pregnant workers in medical facilities where ionising radiation is used. *Publication 90* (ICRP, 2003a) critically evaluates and summarises the effects of pre-natal irradiation, including evidence from animal studies which are particularly relevant to veterinary practice.

(41) In humans, for most properly conducted diagnostic radiology procedures, doses typically do not exceed 20 mGy although interventional procedures involving the pelvis could be higher. If such an examination is medically indicated, the risk to the mother of not doing the procedure is almost always greater than the risk of potential harm to the fetus. However, therapeutic or other higher dose procedures can result in much higher risk. If possible, it is recommended medical radiation procedures should be tailored to reduce fetal dose in pregnant (human) patients (ICRP, 2000; Mathews et al., 2013; ACOG, 2017). Similar effects, risks, and management strategies apply to animal patients, particularly as a lot of evidence for teratogenic effects comes from animal studies, as mentioned above (Benjamin et al., 1998; Russell, 2013).

3.3. ICRP framework of radiological protection

(42) The primary aim of the system of radiological protection is to contribute to an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such

exposure (ICRP, 2007a). For people, radiation exposures are managed with the goal of reducing stochastic effects to the extent reasonable and preventing unnecessary tissue reactions in healthy tissues (e.g. in radiotherapy, a tissue reaction may be unavoidable in order to obtain effective treatment). It should be stressed here that the Commission's system of protection has been developed with the primary aim to protect humans. More recently, environmental protection has also been addressed, in which the focus is on protection of populations in the natural environment. Although in general population-level environmental protection is based on knowledge of the effects of radiation on representative animals and plants, little concern has been demonstrated for the possible detrimental effects for an individual animal, except for those belonging to endangered species, although as early as the 1930s it was acknowledged that attention to animal patient exposure should not be neglected (Wantz and Frick, 1937). Of note is that *Publication 146* does include explicit consideration of pets and livestock in its discussion of emergency preparedness and response (ICRP, 2020b).

(43) It is worth re-emphasising that veterinary practice has always been included in the system of radiological protection in the broad sense but is explicitly addressed and elaborated upon here. As such, much of the information herein regarding radiological protection of veterinary staff and members of the public, including animal owners and handlers, is to a large extent drawn from *Publications 103* and *105* (ICRP, 2007a,b). The Commission recommends that the system of radiological protection be applied in veterinary practice principally for the protection of humans and now also includes explicit attention to the radiological protection of the exposed animals and the environment, where applicable.

3.3.1. Exposure situations and categories

(44) Different exposure situations and categories are defined within the system of radiological protection to take into consideration the specific circumstance under which an exposure occurs. The exposure situations include planned (situations in which protection can be planned ahead of time), emergency (unexpected situations, such as accidents, that may necessitate urgent intervention), and existing (situations that already exist and may need a decision on management or control). The radiological, nuclear medicine and radiotherapy procedures performed in veterinary practice discussed in this publication are considered planned exposure situations.

(45) Exposure categories include public (exposure received apart from occupational, medical, and natural background), occupational (exposure received at work due to the nature of the work), and medical (exposure received as a patient/research volunteer or from a patient as a comforter/carer). As the recommendations are currently written (ICRP, 2007a,b), the medical exposure category appears to apply solely to human medicine. Veterinary applications of ionising radiation are to a very large extent comparable to human medical exposures; in fact, the only distinction is that the exposures are aimed at animals in one case, human subjects in the other. In both cases occupational and public exposures may occur. Because veterinary practice appears to fall somewhere in between, or at the intersection of, the above exposure categories, local governments and regulatory agencies manage veterinary exposures in different ways. Where veterinary practice is often considered—from a regulatory perspective—as comparable to an industrial application of ionising radiation rather than a medical one, this may lead to an approach whereby the animal is considered a mere object, without consideration of its characteristics as a sentient living creature.

(46) Environmental exposure (that is, exposure to the living environment) is a fourth type of exposure. Thus far, the ICRP has focused on the natural environment, with the goal of maintaining biological diversity, conserving species, and maintaining the health status of associated habitats, communities, and ecosystems (ICRP, 2003b, 2008, 2009, 2014, 2017b, 2021a).

3.3.2. Principles of protection

(47) The core of the system of radiological protection consists of three fundamental principles: justification, optimisation, and application of dose limits (ICRP, 2007a). The principle of justification specifies that any activity or intervention that changes the exposure scenario should be overall beneficial to individuals and/or society (see section 6.1). The principle of optimisation of protection and safety specifies that doses should be as low as reasonably achievable (ALARA), considering economic and societal factors as well as other relevant aspects of the prevailing circumstances (see section 6.2). Of note is that in medical exposures, optimisation involves keeping patient exposures to the minimum required to achieve the desired medical objective, whether diagnostic or therapeutic (ICRP, 2013a). Justification and optimisation are source-related principles, and restrictions on dose from a particular source (e.g. dose constraints) are used to avoid severely inequitable outcomes of the optimisation process. The final principle, application of dose limits (see section 6.3), is individual-related, applies to planned exposure situations, and indicates that radiation doses should not exceed appropriately established limits for radiation workers and the public (Table 3.1).

Table 3.1. Summary of the dose limits recommended by the ICRP.

Type of dose limit	Limit on dose from occupational exposure	Limit on dose from public exposure
Effective dose	20 mSv y^{-1} averaged over 5 years, with no single year exceeding 50 mSv. After a worker declares pregnancy, dose to embryo/fetus should not exceed 1 mSv over the remainder of the pregnancy.	1 mSv y^{-1}
Equivalent dose (lens of the eye)	20 mSv y^{-1} averaged over 5 years, with no single year exceeding 50 mSv	15 mSv y^{-1}
Equivalent dose (over 1 cm^2 skin)	500 mSv y^{-1}	50 mSv y^{-1}
Equivalent dose (hands and feet)	500 mSv y^{-1}	Not applicable

(48) Dose constraints are prospective, source-related restrictions on individual dose to workers and/or members of the public intended to serve as the upper bound of the optimisation goal for that source (Fig. 3.1). Note that dose constraints are not intended to be hard limits. Rather, consistent with the core value of justice, dose constraints are intended to serve as a mechanism for limiting potential inequity that could result from differences in value judgements when implementing the optimisation process. In fact, interpreting constraints as rigorous limits can distort the outcome of the optimisation process (ICRP, 2007a). Dose constraints are initially used within the optimisation process at the planning stage to establish an appropriate level of protection for a given situation and develop corresponding protective actions. The numerical value taken for a dose constraint will

depend on the situation at hand, and could be in terms of individual doses, dose rates, collective dose or a combination of these.

(49) After the planning stage, dose constraints can uncover discrepancies between planning and implementation, or reveal potential changes that warrant additional consideration. In other words, a dose constraint can be thought of as an investigation level used as part of the optimisation process. In fact, the concept behind dose constraints is often used in low dose scenarios such as occupational medical exposure without naming it as such. For example, if a process or procedure is known to consistently and appropriately result in an effective dose of 0.5 mSv over three months, and recently that procedure resulted in 2 mSv over three months, then an investigation would be conducted to discern the root cause of the increase. This increase may have been warranted, in which case no further action is necessary, or it may demonstrate a lapse in proper technique, problem with equipment, or other issues that need to be addressed.

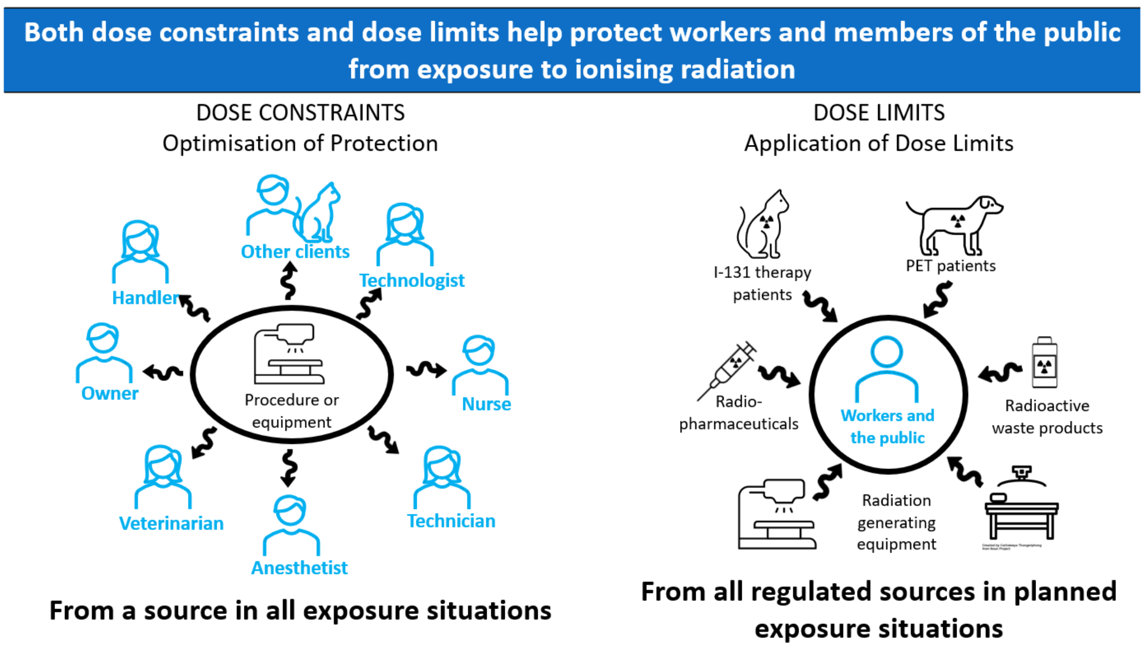

Fig. 3.1. Example comparison of dose constraints (left) to dose limits (right) for protecting workers (occupational exposure) and members of the public (public exposure).

(50) The principle of optimisation of protection for human patients is unique in the system of radiological protection. In diagnostic procedures it is again the same person that gets the benefit but also suffers the risk. The imposition of individual restrictions on patient dose could also be counterproductive to the medical purpose of the procedure. Source-related dose constraints for the individual are therefore not relevant, and thus Diagnostic Reference Levels (DRLs) for a particular procedure, which apply to groups of similar patients rather than individuals, are used. Radiation therapy is also very different from other situations in that the dose is intentional and its potential cell-killing properties are the very purpose of the treatment. In this case optimisation therefore becomes an exercise in minimising doses (and/or their deleterious effects) to surrounding tissues without compromising the pre-determined and intentionally lethal dose and effect to the target volume.

(51) These ideas should intuitively also apply to veterinary animal patients (Pentreath, 2016), although if and how these patients fit within the principle of optimisation has not been explicitly defined. Thus, management strategies are inconsistent between different countries (HERCA, 2012). In many countries, veterinary medicine is considered to be an industrial rather than medical practice, the latter of which is considered to only include human medicine. Unfortunately, this philosophy often neglects considerations associated with unique but necessary aspects of veterinary practice such as safety of animal patients under sedation or anaesthesia, or situation dependent risk management as consistent with a graded approach (IAEA, 2018), that is, the implementation of the system of protection in a way that is proportionate to the magnitude and likelihood of the risk, the complexity of the exposure situation, and the prevailing circumstances. Thus, clear delineation of the application of both justification and optimisation for the patient in veterinary practice is warranted.

(52) Dose limits do not apply to the patient in medical exposures so as not to interfere with necessary, medically indicated diagnostic or therapeutic procedures; generic dose limits might well reduce the effectiveness of the diagnosis or treatment, thereby doing more harm than good. Emphasis is therefore placed on the justification of the procedures in the first place, on the optimisation of protection in relation to the source and, for diagnostic procedures, on the use of DRLs, which are not seen as limits, but instead indicate if a dose received from an imaging procedure is unusually high or low to guide the optimisation process and thus help manage patient exposures (ICRP, 2007b, 2017a). The Commission recommends that an approach analogous to that applied for human medical exposures be developed and applied for veterinary exposures which includes a quality dose management program that allows for periodic audits, continuous peer learning, and use of incident reporting systems that capture incidents and near misses (e.g. https://rpop.iaea.org/SAFRAD/About.aspx or https://roseis.estro.org/).

(53) Derived Consideration Reference Levels (DCRLs), rather than limits, are used to inform the appropriate level of management or control of an exposure in environmental radiological protection. DCRLs are absorbed dose rates above which, for a given taxonomic class, there is the potential for deleterious effects on individuals of a species that may lead to population-level consequences, and they can be used as points of reference to optimise the level of effort expended on environmental protection, dependent upon the overall management objectives and the relevant exposure situation (ICRP, 2014). As such, although relevant to animals in general, the concepts developed for radiological protection of the environment do not suffice for the adequate protection of individual animals exposed in veterinary settings.

(54) Finally, emergency and existing exposure situations utilise reference levels rather than limits, because what defines a reasonable or tolerable exposure is strongly dependent on the prevailing circumstances of the exposure in these situations. The current work on radiological protection in veterinary practice focuses on planned exposure situations, although there may potentially be veterinary concerns in the other exposure situations as well (e.g. emergency exposures following a large-scale nuclear accident). Fig. 3.2 provides a general summary of the principles of radiological protection and associated tools for application in veterinary practice.

Principle	Tools for Application		
Justification *anything that changes the exposure scenario should be overall beneficial to individuals and/or society*	Level 1 *the proper use of radiation in veterinary medicine does more good than harm to society*	Level 2 *a procedure is justified for a specified objective if it does more good than harm to a group of exposed animals*	Level 3 *the particular application should be judged to do more good than harm to the individual patient*
Optimisation *an iterative process for achieving the best level of protection under the prevailing circumstances considering economic, societal, animal welfare, and environmental factors*	Dose constraints *guidelines for upper bound of optimisation in a planned exposure situation for workers and members of the public, based on reasonable, good practice*	Diagnostic reference levels* *indicate whether, in routine conditions, patient dose is unusually high or low for a certain diagnostic procedure*	Derived consideration reference levels *points of reference for optimising the level of effort expended on environmental protection*
Application of dose limits *radiation doses to individuals other than patients should not exceed appropriately established limits*	Dose limits *maximum dose that would be accepted in any planned exposure situations by regulatory authorities*		

Fig. 3.2. The three principles of radiological protection with example tools or administrative strategies for application in veterinary practice. **Note that diagnostic reference levels do not currently exist in veterinary practice but would apply.*

3.4. Potential exposure pathways and practical protection strategies

(55) Ionising radiation can be emitted from an unstable atom undergoing radioactive decay, as is the case with radiopharmaceuticals, or from the acceleration of charged particles, as is the case with radiography equipment and linear accelerators. In other words, there are two broad categories of potential sources of exposure to radiation in veterinary practice: radioactive material and radiation generating equipment. Radiation generating equipment poses a risk of external irradiation for as long as the equipment is ‘on’. Radioactive material poses a risk of both internal and external contamination; for example, if radioiodine is spilled onto uncovered skin, the skin will be externally irradiated, and there will also be the potential for absorption through the skin into the body. Additionally, radioiodine is volatile in its elemental form and thus is potentially an inhalation hazard as well; in general, working with gaseous or volatile radioactive substances poses a risk of internal contamination via inhalation (see section 3.4.2).

(56) The type(s) of radiation emitted by the source will also inform the risk(s) to be considered, as different types of radiation present different exposure pathways of concern. Alpha radiation is unlikely to present an external hazard due to its low penetrating power but becomes a concern if an alpha-emitting radionuclide (such as Ra-223, used in the palliative treatment of bone metastasis) is inhaled, ingested, or gets in the eyes. Depending on the energy, beta radiation may have a range of up to a few metres in air and can penetrate tissue on the millimetre scale. The primary radiological protection concern for beta radiation is exposure of the skin (i.e. ‘shallow’ dose) and eyes (i.e. ‘lens’ dose). Beta-emitting radionuclides are also a concern if ingested, inhaled, or incorporated through the skin. Gamma- and x- rays are penetrating radiations, capable of whole-body exposure (i.e. ‘deep’ dose) as well as shallow dose and lens dose. Thus, different strategies are implemented for dose reduction depending on the specific radiation type, but there are some broad generalisations

applicable to external and internal radiological protection (ICRP, 2007b; Martin, 2013; Johnson, 2017).

3.4.1. External radiological protection

(57) The three basic rules of external radiological protection are reducing exposure time, increasing distance from the source, and using appropriate shielding (Fig. 3.3). These factors need to be considered together in the design of buildings and rooms for veterinary facilities, in the design of radiological equipment (including sealed and unsealed sources), and in local rules and procedures. Protection strategies will include consideration of engineering controls (e.g. shielding, interlocks), administrative controls (e.g. written procedures) and personal protective equipment (PPE, e.g. gloves, lead, aprons), consistent and in conjunction with the management of other workplace hazards (de Castro, 2003).

Fig. 3.3. The three basic rules of external radiological protection: time, distance, and shielding.

(58) Significantly limiting the duration of an exposure is not always feasible, because a certain amount of time is usually required to perform a given task. However, detailed work plans with practice runs beforehand (without the source) can help reduce overall exposure time. If practical, splitting tasks(s) between personnel or rotating through personnel can also reduce an individual's exposure time. Another example of optimising time is the use of 'pulsed fluoroscopy' in both fluoroscopy and interventional procedures, in combination with 'last image hold', which can effectively reduce the time of exposure while keeping required image guidance.[1]

(59) Where reasonably possible, maximising distance from a radiation source is a simple and practical principle for dose reduction. The use of handling tools (e.g. tweezers, tongs) and hand carts should be considered, along with working at 'arm's length' and taking 'one step back' where feasible (Fig. 3.4). However, note that these three basic rules should be used in conjunction with each other, as it could be that using a device like tongs could increase the time spent handling the source (at a greater distance) whereas a short, quick manoeuvre closer to the source may result in less dose. Also, consideration should be given to individuals working for long periods of time in awkward or uncomfortable positions (such as working behinds shields, etc.), which may create an ergonomic/orthopaedic hazard with potential for fatigue-induced mistakes or, again, an increase in the time to complete the task. Where safely applicable, the use of sedation or anaesthesia may considerably reduce the time people need to spend in close proximity to an animal; their radiation

[1] 'Last image hold' refers to the feature of fluoroscopy systems in which the most recent image continues to be displayed on the monitor when fluoroscopy is stopped. See, for example, the discussion of Mahesh (2001).

exposure would then be reduced by the combination of a shorter exposure time and a greater distance from an animal seen as a radiation source. The more fractious an animal, the more personnel will typically have to ‘lean in’ to keep it in position during imaging, and sedation/anaesthesia can make it easier to work at arm’s length or take a step back. Furthermore, sedation/anaesthesia will ease patient positioning, reducing the need for retakes, which will reduce the total exposure time for the personnel involved in restraining animals.

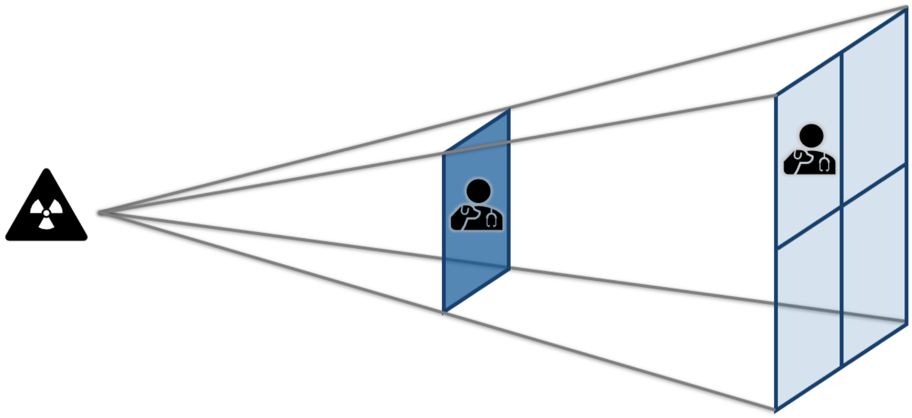

Fig. 3.4. Representation of the inverse-square law. Doubling the distance from a point source of ionising radiation will reduce exposure by a factor of four, as the photons are spread over a larger distance. In practice, this can often be accomplished by taking one step back.

(60) The most appropriate type of shielding to employ is dependent on the circumstance as well the type and energy of the radiation involved (e.g. Fig. 3.5). For example, the electrons (i.e. beta particles) produced in beta decay will interact with their surroundings and produce bremsstrahlung (‘breaking radiation’). Bremsstrahlung refers to the photons produced when the path of a free electron is diverted by an atomic nucleus; the more protons in a nearby nucleus, the more bremsstrahlung there will be. It is therefore better to shield beta emitters with low atomic number (Z) material (e.g. plastic or acrylic glass) as this will block the electrons while producing less bremsstrahlung than high Z material. High Z material is good at shielding photons, so lead shielding can be added on the outside of the primary container to shield the resultant photons while storing or transporting (Fig. 3.6).

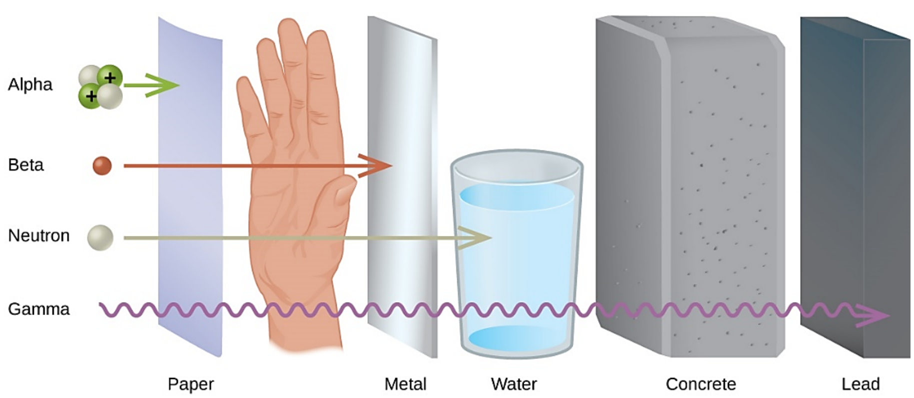

Fig. 3.5. Different radiation types have different abilities to pass through a material. Download for free at http://cnx.org/contents/85abf193-2bd2-4908-8563-90b8a7ac8df6@12.2

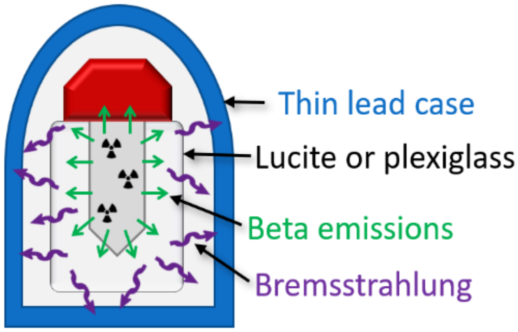

Fig. 3.6. Schematic of shielding a beta-emitting radiopharmaceutical.

(61) Lead is commonly used to shield gamma- and x-ray radiation, but in practice any dense material (tungsten, steel, concrete, etc.) can sufficiently attenuate these photons if thick enough. For example, some high activity sources are housed in basement facilities to make use of the natural, earthen shielding. Photon attenuation is exponential, although for broad beam or poor geometry conditions, scattered radiation can result in 'build-up' and an exposure higher than that predicted purely by exponential attenuation. Personal protective equipment frequently employs lead (e.g. aprons, gloves) or leaded glass (e.g. eyeglasses) to protect radiosensitive organs. Care should be given that use of PPE optimises protection and safety (e.g. considering level of transmission, ergonomic issues, influence on the time required to perform a task, etc.). For example, lead aprons are not appropriate for use in positron emission tomography (PET) studies, as the transmission of annihilation photons (511 keV) through a typical apron is over 90% (Martinez et al., 2012); the increase in work time associated with wearing an apron negates this fairly trivial reduction in exposure.

(62) Shielding should start with assessment of the collective work environment (concrete walls, leaded doors and windows, standing or ceiling-suspended shields, etc.) and be complemented with appropriate personal protective shielding worn by staff and assisting members of the public.

3.4.2. Protection against contamination

(63) As mentioned above, contamination (the unwanted presence of radioactive material) has the unique potential to be both an internal and external radiation hazard. It is also transferable, so specific precautions relevant to preventing contamination need to be adopted. The potential for contamination is relevant for unsealed sources (i.e. radiopharmaceuticals).

(64) Internal exposure to radionuclides is possible through inhalation, ingestion, or absorption through open wounds or even intact skin. Internal radiological protection and contamination prevention measures focus on preventing or minimising the intake of radionuclides into the body and the deposition of radioactive substances on the body. Such protective measures (e.g. confine, contain, enclose) are consistent with general industrial hygiene measures, and generally include strategies for maintaining control of the source and the environment in which the source is handled and used as well as using PPE when appropriate (see section 3.4). Additionally, consistent with the justification principle, the amount of radiopharmaceutical administered to a patient should be selected such that no more is used than that needed to achieve the optimal diagnostic or therapeutic result. This optimises protection and safety of the patient as well as that of workers, the public, and the environment.

4. ETHICS AND VALUES

4.1. Ethics of the system of radiological protection

(65) The system of radiological protection is rooted in, and informed by the three pillars of science, ethics, and experience, and has evolved over the past several decades (ICRP, 2018a). Ethics, or moral philosophy, seeks to distinguish right from wrong; in other words, it considers the nature of morality and strives to describe and justify how things should be and how we should behave. The practical application of radiological protection has evolved in parallel with considerations of the morals and ethics relating to it; one has not directly emerged from the other. Thus, the primary aim of radiological protection is met by way of a comprehensive framework underpinned by a set of fundamental scientific principles and ethical considerations.

(66) *Publication 138* (2018) has recently clarified the ethical basis of the system for human protection and identified core ethical principles (referred to as 'values' to distinguish from the three principles of radiological protection) as well as procedural ethical values underlying the system. It did not address the ethical aspects of the protection of animals.

(67) Three major theories of ethics that underpin the system of radiological protection are utilitarianism, deontology, and virtue ethics, which respectively argue (albeit simplified) for the furthering of the collective interest, the respect for individuals and their rights, and the promotion of integrity, discernment, and wisdom. The core ethical values in relation to humans, considered to be consistent with each of the aforementioned theories and shared across cultures, include beneficence/non-maleficence, prudence, justice, and dignity. Although these values run through the system and are not specific to any one principle, some direct links are clear. Beneficence/non-maleficence, doing good while avoiding harm, relates directly to the principle of justification. Prudence, the ability to make informed and rational decisions in the face of uncertainty, relates to the principle of optimisation. Justice, or the ensuring of social equity and fairness of decisions, relates directly to the principle of the application of dose limits. Dignity, or the respect for all persons, is evident throughout the system and broadly incorporates autonomy, or the capacity to act freely. It also supports the procedural values, which include accountability, transparency, and inclusiveness. Procedural values emphasise the process for implementation of the core values. Hence, ethics encompasses not only what is done but how it is done. Ethical risk evaluation and management, then, considers factors that go beyond the magnitude of the radiation exposure and the cost associated with reducing the exposure (Oughton, 2013).

(68) It is also worth mentioning that although these are the broad values underlying the system of radiological protection, it is not to say that these are the only important values. For example, in environmental protection, additional values such as sustainable development and environmental justice are also emphasised (ICRP, 2003b). Also, since 1979, the seminal principles of biomedical ethics have been beneficence, non-maleficence, justice, and respect for autonomy (Beauchamp and Childress, 2019), which are emphasised in *Publication 1XX* (ICRP, 20XX). As the ethics of radiological protection has been more explicitly addressed for humans, a discussion of the ethics and values associated with the radiological protection of animals follows below.

4.2. Radiological protection and veterinary ethics

(69) The three ethical theories mentioned above are also frequently taught in veterinary ethics (Fawcett et al., 2018). Also, the core ethical values of the system of radiological protection are consistent with, but of course not the only values important in, veterinary practice. For example, the 'One Welfare' framework (Pinillos et al., 2016; Bourque, 2017; Fawcett et al., 2018) recognises and emphasises the interrelationships between human health and well-being, animal welfare, socioeconomic development, biodiversity, and environmental conservation, and highlights additional ethical principles consistent with a holistic approach to sustainable development, similar to but broader than those presented in *ICRP Publication 91* for protection of the environment (ICRP, 2003b). See Annex C for additional discussion.

(70) The consideration of ethics applied to the veterinary practice can help inform the application and implementation of the three RP principles. Although there are numerous ethical values that are relevant to veterinary practice, a few essential, fundamental values are discussed here (see Table 4.1), consistent with the values of the system of radiological protection, the One Welfare approach, and the World Veterinarian Association (WVA) Model Veterinarians' Oath (ICRP, 2003b, 2018a; Pinillos et al., 2016; WVA, 2019). There is not a strict or unique one-to-one link between the values in Table 4.1; in fact, there are many inter-relationships and applications of these and other values that will necessarily come up depending on the circumstances. However, highlighting the dominant relationships between some key values will help make the ethical ties between the System, the environment, and veterinary practice clearer.

Table 4.1. Core ethical values with correlated and procedural ethical values related to veterinary practice.

ICRP 138 Core Value	Correlated value	Procedural value
Beneficence	Reverence for life	Empathy
Non-maleficence	Animal welfare	Accountability
Prudence	Sustainable development	Stewardship
Justice	Solidarity	Inclusiveness
Dignity	Respect for autonomy	Transparency

(71) Veterinarians care for a variety of species of animals, both domestic and wild, and they frequently make use of modern radiology equipment or nuclear medicine techniques. A wild animal may be diagnosed and treated as part of broader rehabilitation and conservation efforts whereas companion and working animals are typically treated for the specific benefit of the animal and its owner. Regardless of the specific motivation for veterinary intervention, ultimately the general goal is to do more good than harm, consistent with the ICRP values of beneficence and non-maleficence. As in human medicine (O'Connor et al., 2019), beneficence is practiced in veterinary medicine not only by treating disease but in expressing compassion and respect for the patient as well as the owner. Through empathy, or the ability to understand and share the feelings of others, we recognise that all living things have a place in the world and deserve to be safe and well, or at the least, to experience life without suffering. In other words, having reverence for life is an expression of empathy (Schweitzer and Cicovacki, 2009). Animal welfare is, of course, the core of veterinary practice. Many definitions and interpretations exist, but animal welfare refers generally to the well-

being of nonhuman animals (Hewson, 2003). Animal welfare can be linked to non-maleficence as the avoidance of causing animals unnecessary harm or suffering. Accountability, one of the original ICRP procedural values, refers to the expectation that a person or institution is answerable for their actions or decisions. To avoid doing harm, we hold ourselves and others accountable. This, for example, would include the tracking and reporting of misadministration incidents or over-exposures, having a plan for such accidents, and learning from them to improve care.

(72) Sustainable development is, broadly, development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The procedural value most closely associated with sustainable development is stewardship. Stewardship is the careful and responsible management of something entrusted to one's care, whether that is the environment, natural resources, a pet, or a farm animal. It is a responsibility that includes prudent decision-making related to those things for which we have an obligation.

(73) Solidarity refers to unity arising from shared responsibilities, interests, and sympathies, which can be implemented through inclusiveness, or involving all relevant parties in the decision-making process. As mentioned above, justice refers to impartiality in behaviours and decisions such that outcomes are as reasonably fair, equal, and as balanced as possible. As an example, the quality and standard of veterinary care should be consistent between patients, regardless of the owner's background. Solidarity is found through the shared desire for the animal's wellbeing, and a decision should be made as to the most reasonable course of action in collaboration with the owner; veterinarians and their staff should of course advocate for and prioritise the animal's welfare, but decisions will also necessarily be made based on economic value and financial means of the owner as well as what the owner is going through (Weil, 1951; Kipperman et al., 2017). In the instance of unreasonable or irresponsible owners, veterinarians should do their best to ensure what is fair to the animal in the given circumstances.

(74) Dignity refers to the shared right of all people to be valued and respected, and autonomy is the capacity to make an informed, uncoerced decision; clearly, one cannot exert their autonomy without transparency, or open and honest communication. For example, available and appropriate diagnostic and treatment options with potential outcomes should be clearly discussed with the owner or responsible party. Owners have the right to know the risks, benefits, alternatives, and financial obligations associated with their animal's diagnosis and treatment. Similarly, workers have the right to know their occupational risks. Moreover, the responsible veterinarian should ensure workers are appropriately (1) informed of relevant risks, radiological and otherwise, (2) trained in the technique or procedure at hand, including radiological protection strategies relevant to themselves, the animal, and bystanders, and (3) protected from unnecessary exposure through practical protection strategies and the provision of proper PPE (see section 3.4). Note that Annex A provides a summary of roles and responsibilities related to radiological protection.

(75) Table 4.1 depicts illustrative relationships between the ICRP core values and relevant correlated and procedural values, but there are a variety of inter-relationships between these and other ethical values or principles. For example, respect for life and sustainable development together support the maintenance of biodiversity, or the variety and variability of life in the world. Although this latter ethical principle is more related to environmental protection (e.g. ICRP, 2003b; UN, 2015), there is overlap in veterinary practice as maintenance of biodiversity is often an active, inter-disciplinary effort that may benefit from access to veterinary expertise. Additionally, beneficence and non-maleficence are almost always considered and balanced together; they are even expressed as a single value in *Publication 138* (ICRP, 2018a). A specific example of the

importance of considering this balance, along with the interplay of empathy, accountability, and stewardship, is the use of research animals. The use of animals for research purposes, either in a laboratory or field setting, is widely recognised as a societal benefit as it has proven invaluable in expanding our fundamental understanding of biology as well as in improving human health, environmental health, and animal welfare (NRC, 1991, 2009; Friend et al., 1999). However, because this can clearly result in harm to the animals concerned, there is also the public expectation that those involved at any stage of the research effort ensure that the animals are used in ways judged to be scientifically, technically and humanely appropriate, avoiding doing harm wherever possible (NRC, 2011). In other words, the research community has stewardship over the animals involved and thus assumes responsibility for the animals' well-being, which necessitates critical and prudent evaluation of study design and outcomes such that discomfort, pain, stress, etc., are minimised (NRC, 2009, 2011; Vasbinder and Locke, 2016). In addition to scientific understanding and experience, elements of empathy can help improve recognition of pain or distress in animals (NRC, 2009; Ellingsen et al., 2010). In this example, accountability is often implemented through legal and regulatory requirements with corresponding consequences for non-compliance (Vasbinder and Locke, 2016).

5. UNIQUE ASPECTS OF VETERINARY PRACTICE

(76) Because many applications of ionising radiation in veterinary practice may have come about without the active involvement of persons knowledgeable in radiological protection—such as a medical physicist as one example—and often also in the absence of an appropriate radiological protection framework, several issues have arisen. These issues need to be identified and rectified, preferably in close collaboration between the relevant stakeholders (e.g. the practicing veterinarians, their professional societies, the radiological protection competent authorities, and radiation protection experts). The issues listed should be seen as illustrative and by no means have the pretension of being exhaustive.

(77) If compared to human medicine applications, challenges for radiological protection could be greater in veterinary practice. Many radiological procedures on large animals are performed in environments that have not been specifically designed, or properly fitted out, for these procedures, including in the field. Justification is not currently supported by a veterinary society's equivalent of the 'referral guidance' or 'appropriateness criteria' we are familiar with in human medicine; there are no DRLs for imaging optimisation; there are important differences with regard to the activities of radiopharmaceuticals administered for therapy purposes for the same disease (e.g. hyperthyroidism) in comparable animals (e.g. average-sized house cats); involvement of a medical physicist is very rare for radiation protection education, training, optimisation, and equipment life cycle issues; and last but not least, not all practitioners performing higher dose diagnostic or even radiotherapy procedures have specific or specialist education and training that is accredited and certified.

(78) Conventional radiology is available in many small veterinary practices. CT-scanners, cone beam CT (CBCT), C-arms or O-arms, and non-mobile fluoroscopy can be found in an ever-growing number of veterinary clinics, where shielding strategies may require particular attention because of retrofitted equipment. The use of mobile radiographic equipment is standard in dealing with large animals as it is performed on farms, in stables, on auctions or in the open field. The delimitation of a safe working area, and the proper use of the mobile equipment may require extra attention. Nuclear medicine diagnostics and treatments are not so common but may have been introduced without sufficient consideration of contamination problems, such as in dealing with radioactive waste, in particular the urine. Some therapeutic interventions may be performed outside of veterinary clinics, such as when radioactive substances are administered into a horse's joints at a riding stable, resulting in potential contamination concerns. In nuclear medicine in general, the animal as an ambulatory radiation and possible contamination source deserves specific consideration, particularly when outside the confines of the clinic. Other radiotherapy treatments, either teletherapy or brachytherapy, are still rare and restricted to veterinary clinics, but the potential radiological risks to both the animals and people involved in the procedures should not be neglected. As an aside, as such treatment options become more available, it is possible that veterinary clinics may face unique nuclear security challenges in addition to the radiation protection and safety aspects described herein.

(79) Although more and more dedicated veterinary equipment is becoming available, second-hand equipment coming from human medicine is still very prevalent in veterinary practice. Safety and performance of the equipment should be verified before their first use and then on a regular basis afterwards, by means of radiological protection and quality control programs, as elaborated on by the IAEA (2021). Mobile equipment may need to be checked more frequently than fixed

installations. Quality checks need to include all pieces of equipment throughout the imaging or treatment chain (e.g. software, cameras in nuclear medicine, image monitors, etc.) and should not be restricted to radiation-emitting equipment or sources. There is also a growing influx of specialty veterinary equipment (e.g. FIDEX CT) that falls under industrial rather than medical standards. Additionally, mobile equipment is being marketed as 'lighter' because shielding has been reduced from, say, 6 kg to 4 kg. Although dedicated, fit-for-purpose equipment is certainly welcome in principle, it must still meet appropriate radiation safety standards. Similarly, clinics may not have given due consideration to shielding needs. For example, a room may have been designed having adequate shielding for conventional x-ray applications on a fixed table with the primary beam directed from the ceiling to the floor, but that room may not be adequately shielded for interventional procedures using a C-arm.

(80) For historic reasons, most veterinarians learn how to use standard radiologic equipment, either fixed or mobile or both, in their basic curriculum. This should comprise at least the basic notions of radiological protection. More risk bearing applications such as the use of CT-scanners, interventional radiology, nuclear medicine, and radiotherapy certainly call for additional education and training, including the corresponding radiological protection. Basic or specialist education and training programs are on offer in a number of veterinary schools and professional societies, for instance through the American College of Veterinary Radiology (ACVR) and European College of Veterinary Diagnostic Imaging (ECVDI), but the corresponding curricula do not always include the necessary theoretical radiation science education and practical training on radiological protection topics specifically. Note that guidance on radiological protection education and training specific to veterinary professionals has been developed by HERCA, inspired by the model developed by the European Commission (EC) for human medicine (HERCA, 2017; IAEA, 2021). Similarly, ICRP *Publication 113* (ICRP, 2009), while focused on human medical care, contains information on education and training that may be useful for informing the development of parallel standards in veterinary practice. Consequently, radiological protection competent authorities may not automatically consider the diplomates (board-certified specialists) as sufficiently competent in radiological protection. One could also ask whether practicing the more complex and risk bearing techniques should not be restricted to veterinarians having successfully gone through 'specialist' programs, as this would be beneficial for the quality of care or service delivered and the associated radiological protection. Across the world, there are striking differences in the basic and specific education and training requirements related to the application of different imaging and therapy modalities in veterinary applications of ionising radiation.

(81) These differences can also be observed for the corresponding radiological protection requirements, where some harmonisation of training requirements is necessary (Gregorich et al., 2018). This effort should include the continuous refreshing, updating, and, where needed, extending of theoretical knowledge and practical skills as well as adapting competencies, attitudes, and behaviours. If other professionals, such as radiographers or radiotherapy technologists, actively intervene or autonomously perform radiologic or radio-therapeutic procedures of any sort, the same principles must apply. They should have successfully gone through initial education and training programs and continue to regularly refresh and update their knowledge, skills, and competencies throughout their professional life. This should necessarily include radiological protection. It is up to the licensee or otherwise authorised person or entity responsible for the facility to clearly establish the roles and responsibilities of all those involved in the procedures, within the bounds of

the appropriate regulatory framework, and ensure that they have, and continue to have, corresponding education and training.

6. APPLICATION OF THE SYSTEM OF RADIOLOGICAL PROTECTION TO VETERINARY PRACTICE

6.1. Justification

(82) As mentioned above, the principle of justification is one of the fundamental principles of radiological protection and states that any decision that alters the radiation exposure situation should do more good than harm (ICRP, 2007a). In addition to the exposure of the animal, veterinary staff are also frequently exposed during veterinary radiological procedures using ionising radiation. Sometimes, the animal's owner or handler, farmworkers, other members of the public or the environment may also be exposed as a consequence of veterinary use of ionising radiation. Hence, proper justification of veterinary radiological procedures is necessary to avoid unnecessary exposures of people, animals, and the environment. It is worth pointing out that the principle of justification is rooted in the ICRP core ethical values of beneficence and non-maleficence, consistent with veterinary deontology. For example, beneficence/non-maleficence is evident in determining whether a procedure fits in the clinical pathway, that is, whether it is indicated and appropriate.

(83) The three levels of justification for a radiological practice in medicine, described in *Publication 105* (ICRP, 2007b), can also be applied to veterinary medicine as recommended herein (Table 6.1). Level 1 justification requires that the proper use of radiation in veterinary medicine does more good than harm to society. As radiological procedures are now integral to veterinary practice worldwide, Level 1 justification is taken as a given and is not further discussed in this document. At Level 2, a specified procedure would be considered generically justified for a specified clinical objective if it will improve diagnosis or treatment of a defined group of veterinary patients or if it will provide necessary information about exposed animals. Level 3 justification requires that the application of a radiological procedure is judged to do more good than harm in the management of the individual veterinary patient. Level 2 and Level 3 justification in veterinary medicine are discussed further in sections 5.1.1 and 5.1.2.

Table 6.1. Summary of the three levels of justification in human medicine and veterinary practice.

Level	Human medicine	Recommended for veterinary practice
Level 1 (General use)	Proper use of radiation in medicine is accepted as doing more good than harm to society. Now taken as a given.	Proper use of radiation in veterinary medicine is accepted as doing more good than harm to society. Now taken as a given.
Level 2 (Specific procedure and objective)	A specified procedure with a specified objective is justified if it will improve the diagnosis or treatment or if it will provide necessary information about exposed individuals.	A specified procedure with a specified objective is justified if it will improve diagnosis or treatment of a defined group of veterinary patients or if it will provide necessary information about exposed animals.
Level 3 (Particular procedure for the patient)	The application of a radiological procedure is justified if it is judged, in advance, to do more good than harm to the individual patient.	The application of a radiological procedure is justified if it is judged, in advance, to do more good than harm in the management of the individual veterinary patient.

(84) There has been increasing awareness about the overuse of radiological procedures in human medicine, with a substantial portion of medical imaging procedures deemed unjustified (Picano, 2004; Holmberg et al., 2010; Malone et al., 2012). While similar surveys have not been carried out in veterinary medicine, the challenge of avoiding unjustified use of ionising radiation likely exists here as well, as many of the drivers of overuse in human medicine (Lysdahl and Hofmann, 2009; Hendee et al., 2010) are also present in veterinary medicine. These include, among others, desire for greater confidence in the clinical diagnosis, lack of awareness of doses and associated risks, defensive medicine, lack of access to previously performed examinations at other veterinary practices, financial conflict of interest, including self-referral and 'self'-presentation. Self-referral means that the same clinician holds the roles of both referrer and of radiological service provider, as 'ordering physician' and as 'imaging services provider' (they may outsource the interpretation but provide the imaging itself). Self-presentation in human medicine may also describe a situation where a person would present at a radiology practice, requesting a procedure for himself or herself, without this request being backed up by a clinician. Similarly, in veterinary medicine 'self'-presentation would then designate the situation in which an animal owner requests for a radiology procedure, without intervention of a veterinary clinician.

(85) Unlike in human medicine, where the potential for overuse due to the financial incentives from self-referral is recognised (Kouri et al., 2002), and where regulations and professional codes of ethics in many countries have been put in place to guard against this practice, self-referral is the norm rather than the exception in veterinary medicine. Radiographic equipment is widespread, both in general veterinary practice and in larger veterinary hospitals. Frequently, the veterinary practitioner ordering a radiological procedure will also be the person performing the imaging procedure and interpreting its results. This person may also be the owner of the radiographic equipment or may be employed by a veterinary practice which explicitly or implicitly expects their staff to ensure return on their investment in radiographic equipment. Hence, financial incentives as drivers for the use of radiological equipment are often present in veterinary medicine and could be considered a risk factor for possible overuse.

(86) 'Self'-presentation, in which the owner/handler of an animal requests a diagnostic imaging or therapeutic procedure without the previous clinical examination of the animal and hence without a radiology referral from a veterinary practitioner, or where the owner/handler demands a diagnostic or therapeutic procedure not considered indicated by their veterinary practitioner, is also a pertinent issue in veterinary medicine. Since veterinary practice is effectively a service industry comprised mainly of private practitioners, some veterinarians may feel compelled to comply with such consumer demands (also relevant in presale examinations) to avoid losing business to veterinary practices that oblige such requests.

6.1.1. Justification of medical procedures

(87) Specialised veterinary radiologists are limited in number worldwide, and most veterinary practices therefore do not have an in-house veterinary radiologist. Hence, the choice of the diagnostic procedure as well as the interpretation of its results are often performed by a general practitioner or a veterinarian of another specialty than radiology, without input from a veterinary radiologist. The radiological procedure is also often performed by someone not specifically trained as a veterinary technologist/radiographer (e.g. a general veterinary practitioner or a veterinary nurse/technician). Appropriate education and training of veterinary staff involved in radiological procedures, either as part of their basic education or as continuing education, is therefore necessary

to ensure both the justification and the optimisation of such procedures. This training should aim to create awareness about the doses and the associated risks from the various radiological procedures. Those completing the training should be able to perform imaging and quality control on equipment, as well as provide effective risk communication with owners and handlers of animals.

(88) Decision support tools, such as referral guidelines or appropriateness criteria (EC, 2014; Subramaniam et al., 2019), could also be particularly useful in veterinary medicine to ensure level 2 justification in the absence of direct veterinary radiologist input. These guidelines should be easily accessible, free of charge and easy to use (e.g. ideally through integration into the electronic medical record system) to ensure their widespread adoption. Such guidelines, however, need to be developed collaboratively by national or international professional veterinary radiology societies, in conjunction with veterinary professional bodies, animal health and regulatory authorities and would require a substantial commitment of time and resources to their creation and periodic update.

(89) Of note is that referral guidelines or appropriateness criteria not only contain information on different radiological imaging procedures (e.g. plain X-ray, CT-scanning) but also on imaging modalities that do not make use of ionising radiation, ultrasound and MRI in particular. From the point of view of justification, but only after careful consideration of all other factors that come into play and are judged equal, the imaging method that can provide the required information for the lowest exposure -or no exposure to ionising radiation at all- should then be preferred, if available.

(90) When new types of radiological equipment are considered and introduced in veterinary practice, an assessment of their potential implications for radiological protection should also be made. Recently, there has been an increase in radiological equipment dedicated to veterinary medicine on the market, and this equipment may not always comply with the imaging quality and/or radiological protection standards required for medical devices. Vigilance, both from potential buyers and regulating authorities is therefore required to ensure that the adoption of such new equipment can be justified.

(91) Level 3 justification requires that the radiological procedure is required for the management of the individual patient. A diagnostic procedure should be able to answer a given clinical question and have an impact on the patient’s diagnosis, prognosis, or treatment. Consideration should also be given to alternative modalities that expose less to ionising radiation or not at all, for example, replacing CT by MRI or ultrasound; one part of justification is determination of the most appropriate exam, within constraints of available modalities. The radiology request should contain sufficient clinical information that a radiologist or an internal or external auditor can assess whether the particular examination is justified.

6.1.2. Justification of non-medical investigations

(92) Imaging of asymptomatic animals for purposes other than medical diagnosis or treatment is frequently performed in veterinary medicine. Screening programs for canine hip and elbow dysplasia are in place in many countries (Verhoeven et al., 2012; Hazewinkel, 2018) and large numbers of animals are thus imaged as a part of the breeding selection process. Many equine studbooks require that a specified radiographic examination has been performed on their approved stallions (Verwilghen et al., 2009), and pre-sale radiographic examinations of yearling racehorses has become standard practice in many countries (Cohen et al., 2006; RIRDC, 2009; Miyakoshi et al., 2017). Other horses, both pleasure and competition horses, also frequently have a radiographic examination as part of the purchase process; insurance companies may demand a radiographic study of an animal as part of the insurance process. The trend for presale examinations is currently

for the inclusion of an increasing number of imaging modalities, radiographic projections, and body areas in the study, sometimes with questionable scientific evidence regarding their value in the evaluation of asymptomatic animals.

(93) For non-medical radiological procedures, Level 2 justification is therefore important. Particular attention should be paid to the scientific evidence for the usefulness of the procedure, ensuring that the chosen imaging procedure is suitable both for the detection of the condition in question and for screening a potentially large number of animals. Furthermore, there should be a demonstrable relationship between the imaging findings and the goal of the screening. For example, for a breeding suitability examination, the trait in question should have a sufficient degree of heritability as well as a prevalence in the population that makes it a relevant discriminator between potential breeding animals, while for presale examinations, the results of the imaging should be predictive of the animal's future performance. Again, appropriateness criteria could be developed by professional veterinary radiological societies, in conjunction with professional veterinary societies, regulatory authorities, breed societies, insurance companies, and industry representatives or other stakeholders, as appropriate.

6.1.3. Benefit and risk of radiological procedures

(94) The balance of benefits and risks to the exposed animals and sometimes more generally the population to which they belong, veterinary staff, animal owners or handlers, the general public, society at large and the environment must all be considered when determining if a given radiological procedure is justified in veterinary practice. This includes full consideration of other modalities that deliver lower or no radiological dose for the indicated need. Along with the beneficence/non-maleficence aspect of justification, finding the appropriate balance will necessarily involve exercising prudence.

(95) Benefits to exposed animals include a direct benefit from improved diagnosis and treatment in the case of veterinary patients, while the results from a presale or breeding suitability examination may help ensure that the animal is suited for its intended purpose and will not suffer negative health consequences from its future use. Screening examinations of asymptomatic animals may help detect subclinical disease, and such early diagnosis may potentially lead to improved treatment results. In addition to welfare benefits to the individual animal, the welfare of animal populations may also be improved through breeding suitability examinations, if undesirable traits or medical conditions can be reduced in the population based on the imaging results.

(96) Benefits to veterinary staff from the appropriate use of ionising radiation include the ability to provide the best possible diagnosis and treatment to their patients, customer satisfaction and financial revenue from the radiological procedures (and any follow up treatment). Owners and handlers may benefit both emotionally and economically from improved diagnosis and appropriate treatment of their animals.

(97) In addition to individual animals, owners and veterinary staff benefiting directly from the appropriate use of ionising radiation—or its alternatives—in veterinary practice, society at large will also benefit from such use. Animal and human health are interlinked, and radiological procedures or other nuclear technologies that contribute to animal health may also improve public health, particularly when they contribute to the control of zoonotic diseases (Viljoen and Luckins, 2012). Furthermore, a healthy population of working animals and livestock will also benefit society, both in terms of public health and economy. Other industries, such as the racing and showing industries, would likely also benefit economically from improved animal health. In the case of rare

or endangered species, conservation efforts may also sometimes benefit from the use of radiological procedures, to diagnose and/or treat disease in zoo animals or wild animals. Moreover, with increasing societal concern over the ethics of the use of animals for production and entertainment, ensuring good health in these animals could also be seen as a prerequisite for the social acceptance of such use.

(98) Radiation risks to exposed animals include both the risk of stochastic and deterministic radiation effects. While stochastic effects predominate in plain radiography, high dose diagnostic procedures, such as CT-guided and other interventional procedures are increasingly performed in veterinary medicine and could potentially result in deterministic effects. Furthermore, in veterinary radiation therapy, adverse effects associated with tissue reactions are frequently encountered in normal tissues and the probability of their occurrence must be carefully balanced against the clinical benefits of tumour control or palliation. On the other hand, lack of access to appropriate diagnostic imaging or therapy or inappropriate choice of diagnostic or therapeutic modality could lead to adverse health effects for the animal due to misdiagnosis or inappropriate treatment.

(99) Veterinary staff receive most of the radiation doses associated with veterinary radiological procedures, either when operating radiological equipment, holding image detectors, or restraining animals during diagnostic procedures, performing or assisting in nuclear medicine, interventional or therapeutic procedures, or caring for animals after nuclear medicine diagnostics or therapy with sealed or unsealed radioactive sources. Most doses to staff will be low (see 6.2.2), but over time could potentially contribute to the development of stochastic effects. Additionally, epidemiologic studies of radiation workers in human medicine note an association of higher incidences of cataracts in both interventional proceduralists and nuclear medicine technologists who receive chronic low dose exposures (ICRP, 2012b). Higher dose procedures, such as long interventional ones, potential spills in nuclear medicine, or accidents relating to therapeutic procedures could potentially lead to deterministic effects. Owners or handlers exposed to radiation when assisting in radiological procedures or caring for animals after nuclear medicine procedures, may also be at risk—albeit low—mainly for stochastic effects. The assistance of laypersons in radiological procedures is currently a subject of debate and will be further discussed in the following section (see section 6.2.1).

(100) Environmental contamination may also occur after diagnostic or therapeutic nuclear medicine procedures, either through releases from the veterinary facility where the procedure is carried out or through radioactivity eliminated from the animal after its discharge from the veterinary facility. While releases at the veterinary facility are often well controlled and regulated, uncertainty exists after the animal is discharged. These uncertainties will depend on the level of radioactivity in the animal at the time of discharge, the mechanisms of elimination of the radionuclide used, the veterinary practices' recommendations for isolation of the animal and management of its waste, as well as the degree of owner or handler compliance with these recommendations. Environmental contamination may lead to radioecological effects, as well as to human exposure through external radiation or internal contamination. The nature and extent of the consequences of environmental contamination will depend on the type, amount, and duration of the contamination event (ICRP, 2014).

6.2. Optimisation

(101) In the system of protection, 'optimisation is always aimed at achieving the best level of protection under the prevailing circumstances through an ongoing, iterative process' (ICRP, 2007a). Optimisation in any practice including veterinary care is a process for ensuring that the likelihood and magnitude of exposures and the number of individuals exposed are as low as reasonably achievable (ALARA) considering economic, societal, animal welfare, and environmental factors.

6.2.1. General considerations

(102) Although the protection and safety of humans may be considered the priority of optimisation efforts, it is important to realise that this can already be largely achieved by limiting the initiating exposure of the animal to what is truly necessary for achieving the clinical objective. Reducing the exposure of the animal will indeed almost invariably be beneficial for the protection of humans involved in whatever way in the veterinary procedure and, where applicable, of the environment. A first step in the optimisation of radiological protection during a veterinary procedure is therefore to adjust the imaging exposure parameters or adapt the activity of radiopharmaceutical administered in such a way that the required clinical effect is obtained with the lowest possible radiation dose and net benefit is maximised.

(103) Radiological exams are now common practice from a young age (screening tests) and for the life of certain animals. Pet animals tend to live much longer than they used to due in part to robust veterinary care, including earlier diagnosis and specialised medicine (Cozzi et al., 2017). With the increase in prevalence and frequency of radiological exams, and the increased lifespan of companion animals, there is a corresponding increase in the risk of radiogenic effects in this population. These facts call for more attention to optimisation of protection and safety in veterinary procedures that explicitly include radiological protection considerations with regard to the exposed animals.

(104) Optimisation can generally be achieved by (1) appropriate design and construction of installations, careful selection of equipment; and (2) day-to-day strategies such as adequate and regularly updated education and training of staff, clarity with regard to their exact roles and responsibilities, regular checks of equipment performance, systematic application of procedural rules, all this embedded in a safety culture at organisation level. This approach is consistent with what is advocated for the practice of human medicine (ICRP, 2007b). However, since the specific risks induced by radiation exposure in animals are not yet quantified, currently no guidance is available related to, for instance, animal specific DRLs. Considering the societal value of animals, though, optimisation strategies relevant for human patients should be valid for animal patients as well.

(105) Optimisation should not be confounded with dose minimisation. Too much focus on dose reduction alone may impede the diagnostic or therapeutic quality of the procedure and result in suboptimal care or necessitate a repeat procedure. This clear distinction between dose optimisation and dose minimisation is critical in radiotherapy, where underdosage may lead to insufficient tumour control and even optimal procedures may result in the inevitable appearance of early or late side effects. Moreover, risk induced by the radiation exposure is only one of the elements to be taken into consideration and optimisation of protection and safety therefore needs a holistic view comprising not only broad animal welfare considerations but also general safety aspects for staff members and members of the public.

(106) Veterinarians and associated staff face many occupational challenges and hazards, of which exposure to ionising radiation is just one. For example, other hazards such as bites, scratches, or kicks may be more important, and certainly more acute issues. Thus, the optimisation process for veterinary workers should broadly encompass consideration of risk, benefit, and practicality. In other words, the level of protection should be optimised in a way that most reasonably accounts for the given circumstances, as consistent with other exposure situations. Gloves might be worn when handling a patient prone to biting, but if said patient is afraid of gloves to the extent that an exam cannot be conducted, it may be prudent to leave them off and consider an alternate strategy.

(107) Similarly, sedation and anaesthesia are frequently advocated from a radioprotection point of view, but in some cases the associated detrimental impact on the animal's health may lead to the conclusion that this may not be the best option for patient restraint. Where permitted, optimisation could then consist in having the owner restrain the animal, even though this might result in some radiation exposure to this person, which in turn should be mitigated by providing clear instructions and -where applicable- adapted protective equipment.

(108) Optimisation clearly also applies to members of the public, defined in the system of protection as individuals who receive an exposure to ionising radiation that is neither occupational nor medical (ICRP, 2007a). With respect to veterinary practice, the public may include pet owners/handlers, clients in a waiting area, farm hands assisting with an equine exam, etc. In some countries, laypersons will not be allowed to assist in veterinary radiological procedures. Where laypersons can be allowed to assist in some procedures (see §114 for example), the following conditions should be fulfilled: 1) the procedure is justified, 2) the person's presence is overall beneficial from a 'holistic' perspective as discussed above (see §105), 3) the person, after having received relevant information regarding potential risks, agrees to undergo some limited exposure (with a dose constraint of the order of a few µSv maximum) and 4) after having been instructed on how to behave (where to stand, where to put their hands, possibly what protective equipment to use, etc.) in order to minimise their exposure. Children or pregnant laypersons should not be allowed to assist in such radiological procedures.

(109) Given the great number and diversity of elements to consider in any specific case, optimisation needs to be tailored to best fit, within the boundaries of what is prudent and reasonable, and the needs of each case individually. This individual approach should first consider the clinical needs, but also the whole environment in which the procedure takes place (e.g. owners' wishes, location and transport facilities, available equipment, etc.).

(110) Prudence is highly relevant to the process of optimisation, consistent with other areas of veterinary practice that use potentially harmful substances or principles; for example, if 50 mg of a drug would suffice to obtain the desired clinical effect, it would not make sense to use 100 mg. Considering the wide variety of risk factors present in a given circumstance and making value judgements as to the most reasonable choice necessarily involves prudence. In situations that are unfamiliar, rare, or without precedent [as may be the case with exotics or zoo animals (e.g. Adkesson and Ivančić, 2019; Schilliger et al., 2020)], it may be prudent to consult a qualified expert (board certified veterinary radiologist, radiation physicist, safety officer or other individual with recognised competence in radiation safety) in advance of the procedure for guidance.

6.2.2. Optimisation in veterinary radiology

(111) The main source of veterinary occupational exposure is from diagnostic radiography (UNSCEAR, 2010). Occupational exposures from this modality are mainly due to scattered

radiation, so individual effective doses should be low. However, it has long been recognised that poor practice may result in unnecessary exposure (Wantz and Frick, 1937; UNSCEAR, 2010). Additionally, we know from human medicine that doses to staff and patients from more modern, higher dose modalities can be consequential for both patients and staff. This is even more pronounced in interventional procedures (Wagner, 2007; Miller et al., 2010; Balter and Miller, 2014; ICRP, 2018b). Of note is that education and training of staff is crucial for optimisation. Guidance material, such as infographics or posted signage, can be very helpful in that respect (see Annex B for an example) (Root et al., 2020).

(112) Radiologic procedures should be performed in an adequately safe environment. The room should be spacious enough to allow people to keep sufficient distance from the radiation sources. And it should be equipped with shielding commensurate with the procedures performed. Hazards may arise when in a room initially conceived for occasional standard small animal radiographic procedures, has become a room in which CT- or interventional procedures are now being performed or simply when the number of procedures performed rises well beyond those that were taken into consideration when the room was first conceived and constructed.

(113) To limit unnecessary public exposure, a designated or controlled area for radiological exams or therapy procedures should be established and physically demarcated with warning signs (e.g. Fig. 6.1). As many equine radiography exams are performed in stables with mobile generators, additional measures should be taken to delineate the exposure area to avoid unforeseen exposure of members of the public not involved in the examination. Performing such procedures in stables with solid concrete or brick walls should be preferred where this is possible, because of the shielding offered. Placing signage at the entrance can then suffice. If procedures need to take place in the open field, delineating the controlled area with appropriate signage is much more demanding as it needs to consider all risks involved, not just radiological hazards.

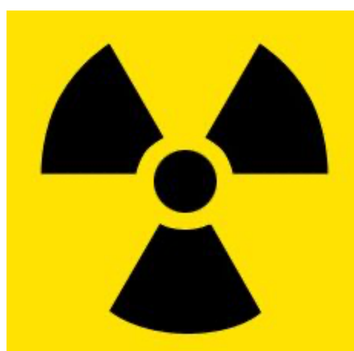

Fig. 6.1 The trefoil radiation warning sign.

(114) In general, members of the public should be kept outside controlled radiation areas, and in the small animal veterinary setting, pet owners should typically not be asked to help during radiological procedures. However, there may be some circumstances in which an owner's presence comforts the animal in a significant way, resulting in a more efficient and, in some cases, physically safer exam. This is turn could reduce the overall exposure of the technologist, for instance by reducing the need for repeat exposures. In other instances, it might be inappropriate to include members of the public or comforters/carers due to the nature and frequency of the exposure and/or the characteristics of the person considered. For example, a young person working at a stable may want to assist in every horse's radiograph series, yet this would likely do more overall harm than

good. The decision on whether to allow lay-person assistance in an exam results from a balancing exercise of pros and cons and is similar to that in human paediatrics (parents, carers, but here owners, handlers) (ICRP, 2013b), and needs to be made prudently, focused on beneficence and non-maleficence, and considering the prevailing circumstances. Minors and those who are pregnant need specific consideration and may be legally excluded from participating in such activities. If the presence of members of the public is judged required or useful, then rotation of these persons may be considered so as to limit the exposure of any single individual. Similarly, when deciding on where to perform a procedure, it may be that leaving an animal in a familiar environment (e.g. a horse at its stable) may bear more risk of radiation exposure yet be overall beneficial, and thus the most reasonable and optimised choice.

(115) Any individual involved in a radiological exam should avoid—as much as possible—being exposed where the radiation field is highest, such as in the primary radiation beam. Where reasonable, positioning and immobilisation aids and/or patient sedation/anaesthesia should be considered to reduce staff and comforter/carer exposures. Similarly, when possible, personnel should stand behind fixed or mobile protective shields; for example, exposure of the head, neck, and upper body of the veterinarian performing an interventional procedure can be greatly reduced by the adequate use of a ceiling-suspended shield. Optimally, neither portable x-ray generators nor the associated cassettes should be handheld. In some cases, such as with interventional radiology, it is necessary for staff to perform a variety of jobs within the radiation field for varying times and at different distances from the source. Where external radiation exposure is a concern, in addition to the use of protective shields, the use of shielding PPE should be considered, including protective wraparound aprons, hand/forearm protectors, thyroid collars, and eye protection (e.g. lead safety glasses), depending on the specific circumstance. It should be borne in mind that leaded gloves only provide limited protection when the hands are positioned in the primary x-ray beam, which should always be avoided. Shielding properties of the PPE selected for a procedure should be balanced against other workplace hazards. For example, the weight of a lead apron can result in orthopaedic issues such as strain on the lower back if worn for long periods of time (Martin and Sutton, 2015; Alexandre et al., 2017). This, along with the restriction of movement, can increase working time as well as result in physical injury, thus, a vest/skirt configuration or the use of lighter aprons, made of so-called lead-equivalent materials, may be preferred. Similarly, wearing radiation protective gloves while working close to the animal's irradiated body volume will reduce dose to the extremities and are frequently warranted (Stoeckelhuber et al., 2005). However, use of these gloves will also negatively affect dexterity and range of motion which might lead to safety concerns associated with increased muscle fatigue and working time (Martin and Sutton, 2015).

(116) With respect to equipment, optimisation of radiological protection involves ensuring that radiological equipment is suitable for the task at hand, and that technical parameters are adequately tailored to veterinary patients and veterinary working routines. The use of radiological equipment in a veterinary setting may be off-label (i.e. not used as originally intended or designed) for new or refurbished medical equipment or dedicated to veterinary practice by design. For all types, it is recommended that the manufacturer continue to maintain the equipment and that no modification occurs that would decrease image quality and/or radioprotection properties (e.g. inner shielding, collimator). For equipment specifically designed for veterinary use, the manufacturer is often able to alter the components of the equipment for which medical standards are no longer legally 'needed' (no established standards of installation and performance). Such changes often have a positive impact on the selling price of the equipment yet possibly a negative impact on image quality, output

stability, and radiological protection of the animal patient, the veterinary professional, and members of the public. For example, reduced inner shielding of portable radiography units results in significantly increased leakage and scatter. In a number of countries, industrial standards are applied when dealing with veterinary equipment and this may be insufficient both from a veterinary care and radiological protection perspective. The Commission therefore recommends that adequate, fit-for-purpose standards be applied on all equipment marketed and used in veterinary applications of ionising radiation and suggests that responsible authorities consider applying appropriate standards for the accreditation of the equipment and for the credentialing of staff members. Ideally, these standards would be internationally recognised as manufacturers often sell equipment in multiple countries. Of note is that equipment standards should also include requirements on the device connections that allow installation in a dedicated veterinary room (e.g. light signalling at the room entrances, emergency stops, door switches).

(117) Optimisation measures for patient protection in diagnostic radiology, for the same image quality, should be discussed with the manufacturer and installation engineer and implemented when possible. This would include considerations such as limitation of views to those necessary for common diagnostic protocols and technique charts for the range of animal sizes relevant to the facility. Similar strategies apply for CT examinations with a special procedure for auditing repeat examinations and requests for systematic whole-body imaging. Standardisation of national referral guidelines for when and what imaging should be done for common situations and then standard protocols that describe how to perform the imaging examination would greatly aid the veterinary practice worldwide in caring for animals and increasing radiation safety. Examinations should not be repeated if no clinical benefit would be obtained. In other words, aesthetically pleasing images should not be the preponderant consideration, but instead that the image quality is sufficient to confidently make a diagnosis or proceed with an interventional procedure with the lowest possible exposure. The priority for a diagnostic image is that it is interpretable, which relies on not just the physics of the image (e.g. resolution and contrast) but also factors like how and where the data is displayed, the ambient environment, and the experience of the person reading the images. Reasonable reduction of the animal dose and improvement of study quality contribute to the optimisation of protection and safety by reducing doses received by both the animal patient and staff.

(118) A highly important step in optimisation of radiographic procedures of any kind is to limit the exposed tissue volume to what is relevant for the clinical case at hand. In standard diagnostic radiology and interventional fluoroscopy this should be achieved by appropriate beam collimation, in CT by scan length limitation. These simple measures lower patient dose and -by reducing radiation scatter generated in the exposed tissues and materials- improve image quality and reduce the exposure of professionally exposed persons as well as members of the public.

(119) A prerequisite for optimisation is a thorough knowledge of the doses associated with a given exposure situation, as well as the factors that influence this dose. Reported doses per image to persons participating in radiographic examinations of small and large animals (Ackerman et al., 1988; Hupe and Ankerhold, 2008, 2011; Barber and McNulty, 2012; Eckert et al., 2015), or per examination for personnel present during standing CT examinations of the equine head (Dakin et al., 2014), fall in the range from 0.1 μSv – 34 μSv. Doses towards the higher end of the range are typically encountered when thicker body parts are being radiographed, such as the abdomen in large dogs or the equine head, spine (especially thoracic and lumbar region), and proximal extremities. While several of the above studies state that estimated annual doses will be well below

regulatory limits for a given caseload, other studies of occupational doses in veterinary medicine have found that personnel doses may approach annual dose limits recommended by ICRP (Table 4.1) (Hernández-Ruiz et al., 2012; Canato et al., 2014). Recently, dosimetric data has been published for veterinary interventional radiology and intraoperative fluoroscopically guided surgery, where there is close proximity between personnel and veterinary patients during exposure, often for extended periods (Sung et al., 2018; An et al., 2019; Hersh-Boyle et al., 2019). Reported operator dose levels may approach or even exceed regulatory limits, which emphasises the need for both quantitative radiation monitoring and the use of appropriate protective measures during these procedures.

(120) With regards to dose to the animal patient, few dosimetric studies have been published. Primary beam doses or entrance surface skin doses, typically in the order of 1 mGy have been reported with the aim of assessing their contribution to personnel dose (Veneziani et al., 2010; Barber and McNulty, 2012). Dosimetric publications aimed at the radiation protection of the veterinary patient are however emerging. Nemanic et al. (2015) addressed the potential of lead shielding to reduce animal dose during elbow radiography in dogs, and Hersh-Boyle (2019) reported radiation exposure of dogs and cats undergoing intraoperative fluoroscopic procedures. In the latter study, doses up to 617.5 mGy were reported. However, systematic reporting of dose descriptors such as the dose area product (DAP) and CT dose index (CTDI) for clinically relevant protocols, both within and between institutions, are lacking in veterinary medicine and hence, diagnostic reference levels (DRLs) do not exist. Furthermore, while the relationship between these dose descriptors and radiation risk in the form of effective dose has been established in human medicine through the use, for example, of anthropomorphic or patient-based voxel phantoms and Monte Carlo simulations, such links still have to be established in veterinary medicine (although as mentioned earlier, some phantoms such as these have been developed for animals, including canines). The number of different species involved, as well as the range of patient sizes within a species may be relevant challenges in veterinary medicine.

(121) More dosimetric data is needed, both for personnel and veterinary patients, particularly for potentially high dose procedures, such as interventional radiology fluoroscopically guided surgical procedures. Furthermore, as CT interventional procedures become more prevalent in veterinary medicine, dosimetric aspects of these procedures should also be addressed. Systematic reporting of dose descriptors for clinically relevant protocols will be necessary to compare such protocols both within and between institutions and thus to optimise such protocols with respect to dose. The relationship between dose descriptors, organ doses and associated radiation risk also must be determined for veterinary medicine.

6.2.3. Nuclear Medicine

(122) Nuclear medicine procedures involve both external irradiation and contamination hazards. Unsealed sources such as radiopharmaceuticals have the potential to land on the skin or directly be taken into the body, so care should be taken to employ reasonable methods for reducing this risk of contamination. The radiopharmaceutical, the animal to which it has been administered and all substances then produced by the animal, in particular the urine, are also potential contamination sources. All these should be properly managed, so facilities should be designed and operated (e.g. careful source management, regular checks on possible contamination of the work environment, waste collection and disposal) to reduce the risk of exposure and of unplanned releases of any of these into the environment. Practical strategies for reducing time spent nearby, increasing distance,

and using appropriate shielding should at the same time be applied to reduce exposure to external irradiation.

(123) Safety measures to prevent contamination with radioactive substances can be implemented at the source or the worker and are consistent with general industrial hygiene practices for protecting workers from non-radioactive contaminants. Example methods for confining or containing a radioactive source include storing radioactive material in a secure, shielded location, limiting the handling of radioactive materials to well-defined areas within a practice (e.g. a secure drawing up area with appropriate mobile shielding); using secondary containment (e.g. trays, buckets) to limit the consequences of possible spills; using a ventilated hood with sufficient and consistent airflow. Good housekeeping practices (i.e. cleanliness and organisation), regular radiological surveys, and detailed record keeping are also important for the prevention of contamination.

(124) External radiation safety measures follow those described in section 3.4.1; specific examples in nuclear medicine include using an appropriately shielded syringe, using lead containers and/or hand carts to transport the radiopharmaceutical to the receiving patient, and taking one step back from the injected patient where possible.

(125) The PPE used is essentially aimed at preventing contamination risks by the radioactive material involved. For example, when injecting, radiopharmaceutical impermeable gloves, a lab coat (long sleeves) and face mask or shield should be worn to limit skin exposure in the situation of back pressure when injecting into a catheter.

(126) With respect to the patient, it is important to be aware of the potential for deterministic effects in patients undergoing certain nuclear medicine procedures. These effects may be unavoidable to some extent (e.g. therapy). In nuclear medicine therapy, there may well be side effects, for example, effects on salivary glands when treated for thyroid cancer with radioiodine. Of course, there are also the potential consequences of extravasation, that is, when the radiopharmaceutical ends up next to the vein through which it was supposed to enter the body (van der Pol et al., 2017).

(127) It should be kept in mind that the administered activity of a given radioisotope or radiopharmaceutical will to a large extent determine the radiation risks to the animal itself, to humans involved and to the environment. Prudence can provide insight into whether additional dose (activity) should be used to speed up a nuclear medicine procedure or whether longer sedation or anaesthesia would be appropriate. Different situations require different approaches, always considering the ALARA principle. For example, there are two standard protocols in PET imaging, based on the timing of radiopharmaceutical injection and induction of anaesthesia. The protocol in which anaesthesia is induced prior to injection has longer anaesthesia time (up to ~2 hours) but lower radiation doses to personnel compared to the protocol in which anaesthesia is induced after injection. Of note though is that the total annual effective doses to personnel associated with the latter protocol are well within the annual occupational dose limit (max ~5 mSv assuming 100 animal patients per year) (Martinez et al., 2014). Other considerations beyond anaesthesia time and radiation dose include keeping the animal as still as possible during the radiopharmaceutical uptake period in order to avoid unwanted uptake in active muscles.

(128) In order to protect staff, members of the public, and the environment from the consequences of radionuclide administration to an animal, and particularly after therapy procedures, the animal may need to be hospitalised, so that its excrements may be collected and treated as radioactive waste. The risk of contamination from the animal itself usually subsides rather rapidly

because of natural elimination, mostly by kidney through the urine. However, it may take several days or even weeks before the dose rate emitted by the animal has fallen below the threshold values for its release and it can return home (e.g. 3+ weeks in some countries following iodine therapy).

(129) Hospitalisation, particularly for long durations, needs to be considered as a potential welfare issue for both the animal and its owner or carer (Graf, 1999; Boland et al., 2014; Johansson et al., 2014). Again, radiological protection concerns need to be balanced against and considered together with all other values at stake. Hospitalisation creates a stressful situation, especially in small animal pets (dogs, cats) as has now been shown that animals have feelings, likely evolved to protect primary needs (Hewson, 2003; Lloyd, 2017). With the progressively more prominent place that animals, particularly companion animals, have gained in human society, it can be equally stressful for pet owners to have their animal in the hospital for a long duration, as it is for the animals themselves (McConnell et al., 2011; Amiot et al., 2016; McConnell et al., 2017).

(130) In view of the complexity of nuclear medicine procedures on animals, in part resulting from the need to simultaneously manage external exposure and contamination risks, veterinary nuclear medicine should only be performed by veterinarians and staff members that have successfully gone through specialist training programs. This is even more compelling for therapy applications.

6.2.4. External Beam Radiotherapy and Brachytherapy

(131) Optimisation has a crucial role to play in all therapeutic applications of ionising radiation. As such treatments gain prevalence in veterinary care, this importance is increasing both from the perspective of the animals treated and the professionals providing this type of care. For the animal patient, optimisation means making sure that in spite of the very high doses delivered to the target volume and needed to obtain the desired therapeutic effect, the exposure of other tissues and organs is kept as low as reasonably achievable (ALARA). The objective is that deterministic side effects are avoided to the extent possible and that the overall exposure of healthy tissues, particularly of radiosensitive ones, is minimised so as to limit the probability for induction of delayed tissue reactions or second primary cancers.

(132) The high doses and dose rates applied also have the potential of causing serious risks to staff members involved in these procedures. Blocked sources in remote after-loading or accidental ‘beam on’ situations in teletherapy could generate these kinds of risks, whereby other deterministic effects than just skin burns cannot be excluded. Strict procedures must be in place to allow the most optimal and safe use. Such complex and high-risk procedures should only be performed by veterinarians who have completed extensive education and training in radiological protection. From a veterinary care perspective, it may be preferable that the radiological practitioners responsible for these procedures be diplomates of speciality education and training programs, bearing in mind the current curricula may be insufficient when it comes to specifically addressing the radiation hazards. The Commission therefore recommends that the providers of such education and training programs better embrace radiological protection as an indispensable and integrated element of quality care.

6.3. Application of dose limits

(133) All individuals working with radiation in a veterinary practice must do so within the applicable legal requirements to ensure that neither occupational nor public radiation dose limits are exceeded. Although dose limits are maximum permitted values (Table 3.1), all doses are to be kept as low as reasonably achievable. Radiation workers should be subject to personal dose monitoring (where deemed appropriate by risk assessment) to ensure that dose limits are not being exceeded and working procedures are optimised. Except for pregnancy, the basis for dose limitation is the same for men and women, but once pregnancy is declared, additional controls need to be considered to protect the unborn child, reflected with a recommended fetal dose limit (ICRP, 2000).

(134) The concept of *carer* refers to an individual who may be exposed to radiation as a helper providing care for a patient (ICRP, 2007a). Whereas carers are members of the public, they are susceptible to being exposed to doses exceeding public dose limits, which is considered appropriate within reason by the system of radiological protection. Although thus far in veterinary medicine animals have not been legally recognised as 'patients' and thus the concept of a pet owner serving as a 'carer' has not been applicable, it is recommended that the concepts of patient and carer be tailored to be applicable within reason in veterinary practice. Of note is that the suggested dose constraint for carers of human patients is 5 mSv per episode (Table 8, ICRP, 2007a).

6.4. Quality aspects of radiological protection and managerial responsibilities

(135) Radiological protection should be approached with a holistic perspective, covering all aspects of ionising radiation practice. As such, quality aspects of a sustainably effective radiation safety program would include, broadly, consideration of equipment and facilities, education and training, assignment of responsibilities, procedural protocols, follow-up of outcomes, and dose and incident monitoring and reporting. These aspects should be included within the overall quality assurance program and are important to ensure and maintain the best attainable veterinary services.

(136) When fixed installations are concerned, this starts with design and layout of the facility, considering the architectural requirements of the building and rooms, in particular those where radioactive sources will be stored, and ionising radiation will be applied. Important considerations would include, for example, accessibility and access control, the optimal positioning of the equipment, and the shielding requirements for the walls and doors. When mobile equipment is used, similar considerations come into play. In nuclear medicine, where unsealed radioactive sources are used and/or stored, specific attention should be devoted to the safe and secure storage of sources along with the collection and further handling of radioactive waste. In radiotherapy, room shielding and access control are of crucial importance, as is the safe storage of possibly present radioactive sources (e.g. those used in brachytherapy).

(137) The next step is to consider the applications themselves (i.e. the way in which ionising radiation is used). Tasks and associated responsibilities for each procedure or treatment should be explicitly assigned to staff members, so that they know exactly what is expected from them, and that all staff have had, and continue to have, adequate and regularly updated education and training commensurate with these tasks and responsibilities. Members of staff should have sufficient theoretical knowledge, practical skills as well as the right mindset: the attitude to adopt a radiation safety culture while working with ionising radiation.

(138) Equipment should work adequately; this is not limited to radiation emitting devices but should cover the complete imaging or treatment chain (e.g. image displays, planning software, etc.), along with the more obvious items such as shielding equipment, PPE, and dosemeters that serve to protection and monitor staff and, where applicable, members of the public assisting with a procedure. All equipment should be regularly monitored and maintained for adequacy of performance. Making sure that quality services are being consistently provided safely makes the application of procedure guidelines or handbooks necessary.

(139) In the event of incidents, accidents, or near misses, a system should be implemented to ensure these are thoroughly investigated. Any such events should serve as an opportunity for further improvement of radiation and general safety. Reporting of anything unusual should be encouraged and immediate actions to prevent any possible worsening or repetition should be taken until the situation has been fully understood and, whenever applicable, remediated. Learning from incidents, accidents, or near misses could be much more profitable than just for the undertaking where such event occurred; they could in fact be shared between colleagues -for instance through a platform offered by professional societies or international organisations such as the IAEA- as a means to prevent the same or a similar event from happening in a comparable professional context elsewhere.

(140) Systematic follow-up should be made of procedure outcomes, in terms of their contribution to the cure pathway or to the adequacy of the suitability guidance delivered. Such follow-up would be a strong help in constructing or enlarging the evidence base for justification of veterinary exposures.

(141) Finally, doses to animals, staff, members of the public, and the environment, as applicable, should be monitored. The systematic recording and follow-up of dose indicators, and intercomparisons with those registered by others in similar conditions, will contribute to optimisation of procedures and will allow for the early detection of malfunctioning devices or the systematic performance of insufficiently optimised procedures.

7. SUMMARY OF RECOMMENDATIONS AND CONSIDERATIONS

(142) Veterinary use of radiation in the diagnosis, management, and treatment of disease has expanded and diversified considerably over the last few decades. Diagnostic imaging procedures are performed in an increasing number of situations where the animal's health care is not the primary objective of the investigation. These practice changes have come with an increase of exposure-related risks to veterinary professional staff, to members of the public, to the environment and to the animals submitted to these procedures. Radiological protection concerns have therefore increased, and the many unique aspects of veterinary practice compared to human medicine add to these concerns. Radiological protection challenges specific to veterinary practice arise from the different combinations of personnel and members of the public that may be involved and from operational environments required when dealing with animals.

(143) The priority of radiological protection is that of humans, but the animal's exposure should also be the object of explicit attention from a radiological protection perspective in veterinary practice, because like humans, animals are subject to potential tissue reactions or stochastic effects resulting from exposure to radiation. Moreover, animals are not just objects, but sentient living beings able to feel and suffer. In veterinary practice, the core ethical values of the system of radiological protection therefore need to be complemented with correlated ethical values such as respect for life and animal welfare. In addition to the procedural ethical values of transparency, accountability and inclusiveness highlighted in *Publication 138* (ICRP, 2018), the values of empathy and stewardship are needed in the implementation of the system of protection in veterinary practice and in its application to animals in general.

(144) As in all applications of ionising radiation, radiation safety management needs to be commensurate with the implied risks. As risks in veterinary applications have clearly increased and diversified, radiation protection should get more, and more explicit, attention by the full application of the Commission's system of protection. Despite some differences, the radiological protection concerns originating from the use of ionising radiation in veterinary practice is to a very large extent comparable to equivalent human medicine applications and non-medical human imaging. It is therefore recommended that veterinary applications be treated in a comparable way. This recommendation applies to the radiation safety requirements of the installations, but equipment too should meet the standards set for medical devices rather than just industrial standards.

(145) It is recommended that the safe execution of veterinary applications be guaranteed by the implementation a quality assurance program at managerial level. The analysis of incidents and accidents should be part of such a program as it may contribute to the continuous improvement of safety. International organisations and professional societies could set up and recommend the use of incident/accident reporting tools, which could then provide lessons learned to all professionals in a no shame-no blame setting.

(146) Veterinarians and their co-workers should be sufficiently educated and trained in the radiation safety aspects of the applications they make. The Commission recommends that specific applications such as interventional radiology, nuclear medicine and radiotherapy be reserved for professionals that can demonstrate having successfully gone through an education and training program which provides them with the necessary knowledge, skills and attitudes to provide adequate care to the animals whilst taking responsibility for the radiation safety aspects of their activities. This responsibility covers staff and possible members of the public present, the individual animal and the environment, where applicable.

(147) The protection principles of justification, optimisation and dose limits should apply in full to veterinary applications. Thereby, the three levels of justification for radiological practice in medicine can also be applied to veterinary medicine. Level 1 requires that the proper use of radiation in veterinary medicine does more good than harm to society. At Level 2, a specified procedure would be considered generically justified for a specified clinical objective if it will improve diagnosis or treatment of a defined group of veterinary patients or if it will provide necessary information about exposed animals. It is recommended that scientific organisations and specialist professional societies provide guidelines that could assist clinicians in making appropriate choices; examples can be taken from referral guidelines and appropriateness criteria that have been in use in human medicine for years (ICRP, 2007b). Similar guidance would be particularly welcome when presale and insurability examinations on horses (or other animals as relevant) are concerned. Level 3 justification requires that the application of a radiological procedure is judged to do more good than harm in the management of the individual veterinary patient. The balance of benefits and risks to the exposed animals, veterinary staff, animal owners or handlers, the general public, society at large and, where applicable, the environment must all be considered when determining if a given radiological procedure is justified in veterinary medicine.

(148) Optimisation in veterinary care should be considered a process for ensuring that the likelihood and magnitude of exposures and the number of individuals exposed are as low as reasonably achievable considering economic, societal, animal welfare, and environmental factors. Given the great number and diversity of elements to consider in any specific case, optimisation needs to be tailored to best fit, within the boundaries of what is prudent and reasonable, the needs of each case individually. This individual approach should first consider the clinical needs in a health care setting or the added value of a given test in case of non-medical animal imaging procedures, but also the whole environment in which the procedure takes place (e.g. owner wishes, location and transport facilities, available equipment, etc.). The Commission acknowledges that managing the exposure of the individual animal as an integrative part of the optimisation process may be challenging as this type of exposure has not previously been specifically addressed within the context of the system of radiological protection.

(149) Prudence is highly relevant to radiological protection. In a situation where solid proof of a causal relation between low dose exposures and the induction of cancer or hereditary effects in humans is still lacking, the Commission has opted, in its 2007 Recommendations, for the continued application of the LNT model, which assumes that a given increment in dose will produce a directly proportionate increment in stochastic effects (ICRP, 2007a). The Commission recommends that a similarly prudent approach be applied when exposures of animals are concerned, noting also that radiological hazards are just one of many risk elements in veterinary practice and therefore needs to be considered in the context of the complete procedure.

(150) This publication, being meant for a broad audience, provides a general overview of the issues and concerns related to radiological protection in veterinary practice. The intent of current ICRP publication is to explicitly acknowledge the importance and unique aspects of radiological protection in veterinary practice, lay the foundations, and develop additional guidance in the future, similar to the approach for radiological protection in human medicine. For detailed, practice-oriented guidance, the IAEA has developed a thorough report with modality specific approaches to radiological protection (IAEA, 2021). The Commission hopes that highlighting radiological protection concerns and related knowledge gaps will inspire additional research and development related to the evidence-based use of ionising radiation in veterinary practice in support of the

justification process, dedicated facilities and equipment, improved understanding of the radiosensitivity of different types of animals along with practice guidelines in support of exposure management, and other relevant areas to promote health and safety of personnel, the general public and the environment while further improving the quality of care for the patients and healthy animals submitted to radiological procedures. This is sure to be a collaborative approach between veterinarians and their societies, research institutions, veterinary schools and colleges, radiation protection professionals, regulatory authorities, and other organisations.

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ANNEX A. ROLES AND RESPONSIBILITIES

(A 1) In radiological protection, every party involved has a role and responsibility to contribute to the overall system of protection. That principle also applies to the intervening organisations and authorities. Data regarding the exposure to ionising radiation and the effects observed are gathered on a worldwide scale by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR; e.g. UNSCEAR, 2001, 2010, 2014). These data and their scientific analysis serve as a basis for radiation protection worldwide. In the United States, similar activities are undertaken by the Biological Effects of Ionizing Radiation (BEIR) Committee of the National Academy of Sciences (e.g. NRC, 2006). The ICRP then provides recommendations as on how to manage radiation risks. These recommendations are not only based on the available scientific data, but also on value judgements. These value judgements take into account societal expectations, ethics, and experience gained. Although ICRP's recommendations are illustrative rather than prescriptive, they are generally followed worldwide. The International Atomic Energy Agency (IAEA), together with other members of the United Nations (UN) family like the ILO International Labour Office (ILO), the Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO) make use of ICRP's recommendations to formulate requirements which are binding to their many member countries. These organisations also provide practice-oriented guidance on how to implement these requirements. National governments are then responsible for implementation through their legislative system, which gives room to adapting the specified requirements to fit into the economic, societal and political realities of the country considered.

(A 2) When it comes to veterinary practice, a number of important roles can be identified, each with specific responsibilities with regard to radiological protection. It is important to realise that one single person may hold several roles, even simultaneously, and also that some roles can be attributed to a legal entity rather than to a physical person. It is also worth emphasising that although responsibilities with respect to radiological protection are highlighted here, radiological protection is one aspect of a broader suite of concerns in veterinary practice, and it should be managed in the context of the practice or procedure as a whole.

(A 3) The first role to consider is linked to the installation or location (e.g. a veterinary hospital or private practice), where ionising radiation is being used. There is clear responsibility with regard to the fitness-for-purpose of the building, rooms, equipment (including protective devices), and qualifications of the staff who work there. This responsibility is on-going and should be supported by a quality assurance system, which includes regular quality control of equipment performance, the initial and continuous education and training of staff members, the procedural rules, etc.

(A 4) The next important role is that of the 'radiological practitioner', or the person performing or overseeing the procedure which results in exposure to ionising radiation. Most often a veterinary doctor, the role could also be attributed to a nurse or radiographer who in some countries can perform these procedures independently. It is the radiological practitioner who has the ultimate responsibility for the appropriateness of the procedure in the presenting clinical context, in application of the justification principle: in case another procedure would be requested by a clinician or animal owner, the radiological practitioner should act as an expert advisor. The radiological practitioner is also responsible for the way the procedure is performed and in doing so will have to consider all radiation protection aspects of the procedure at hand. This includes staff exposure, exposure of possibly assisting members of the public such as the owner or handler, and more broadly possible exposure of other members of the public. In nuclear medicine or in radiotherapy when radioactive source materials are being used, protection of the environment should also be considered by the practitioner. In some settings, the radiological practitioner may be assisted for certain technical and practical aspects of the procedure by dedicated staff members, who then become responsible for these particular aspects.

(A 5) Members of the public that will be or may be exposed because of a procedure on an animal should not only be transparently informed about the possible radiation risks but also be instructed on how to behave in order to minimise or avoid these risks. In principle this provision of information and instructions is a responsibility of the practitioner, but it may be transferred to a dedicated staff member. Once duly informed and instructed, the member of the public also becomes responsible for part of the radiation protection, because this person's behaviour may greatly influence their own exposure, that of others, and in some cases, that of the environment.

(A 6) Universities, colleges, and schools are responsible for the adequate education and training of veterinary professionals who perform procedures making use of ionising radiation. Many programs would benefit from more explicitly addressing the radiological protection aspects of these activities. This would allow diplomates (board-certified specialists) to perform state of the art radiological procedures while duly considering the protection of exposed workers, assisting members of the public, the public, the environment, and of the animal examined or treated.

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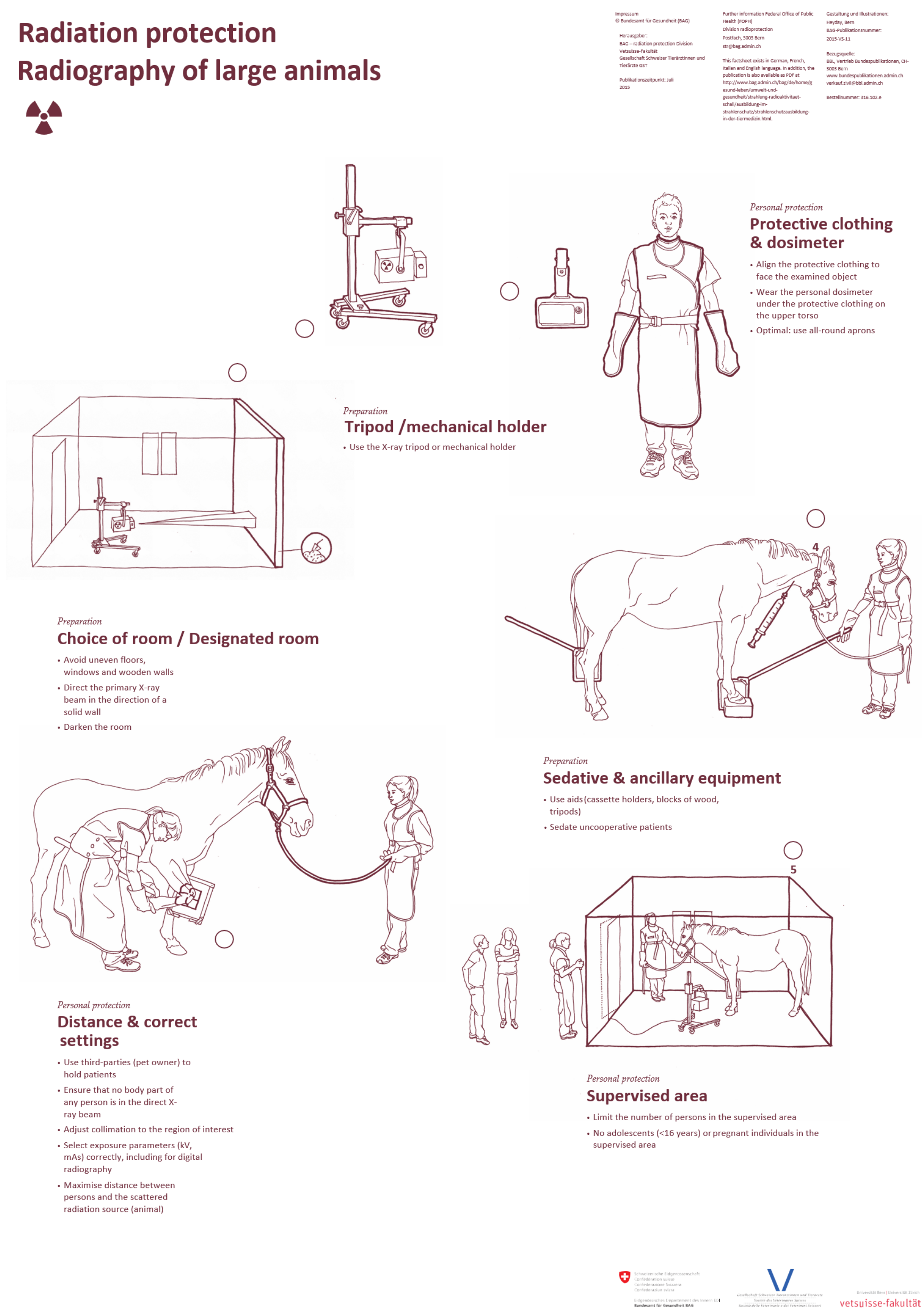
2193 # ANNEX B. EXAMPLE GUIDANCE FOR RADIOLOGICAL PROTECTION
2194 # IN RADIOGRAPHY OF LARGE AND SMALL ANIMALS



2195

2196 Fig. B.1. Example of posted guidelines for radiological protection in large animal radiography. Courtesy
2197 Radiation Protection Division, Federal Office of Public Health (FOPH), Switzerland.

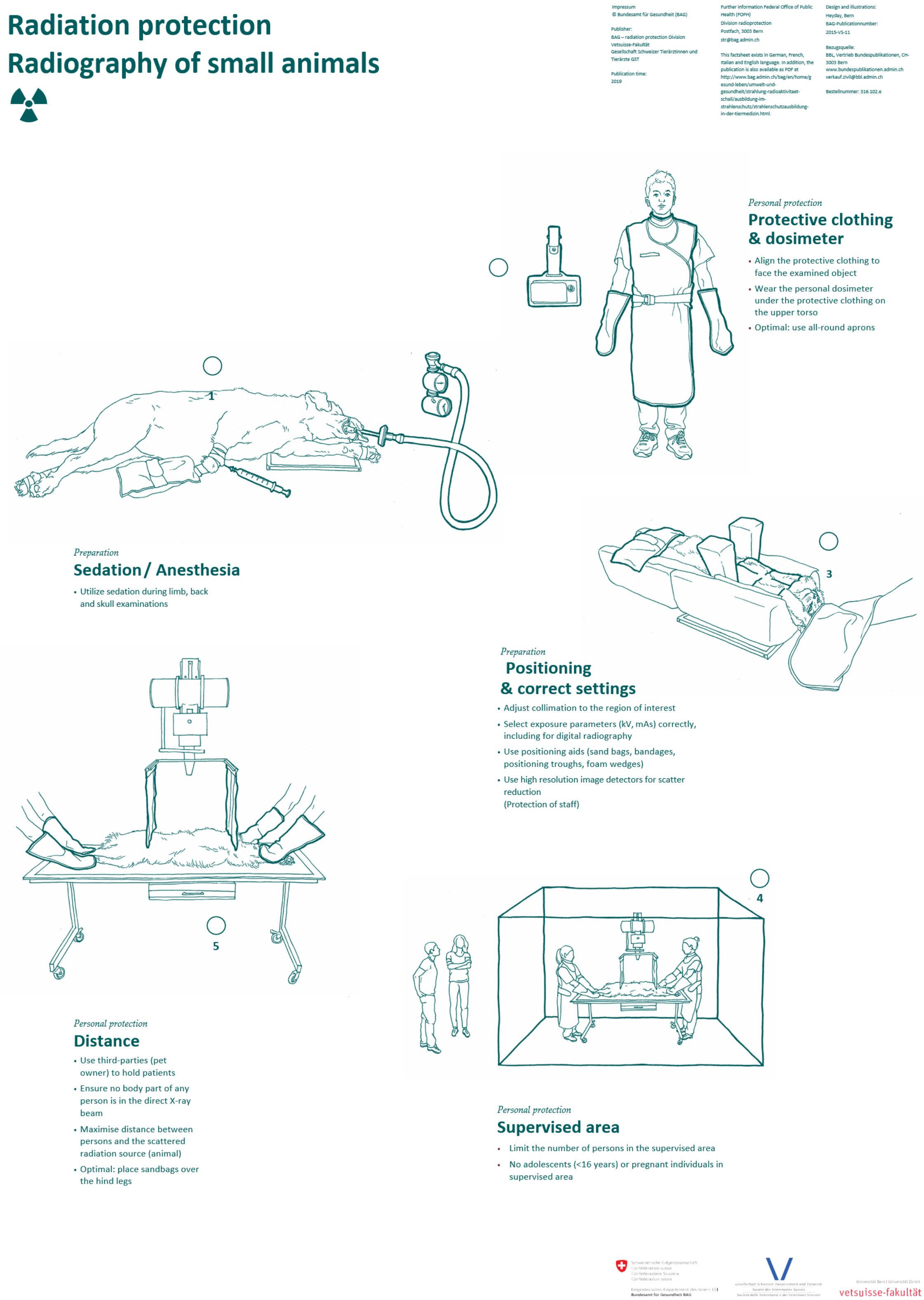


Fig. B.2. Example of posted guidelines for radiological protection in small animal radiography. Courtesy Radiation Protection Division, Federal Office of Public Health (FOPH), Switzerland.

ANNEX C. ETHICAL ISSUES ASSOCIATED WITH THE PROTECTION OF ANIMALS AND THE ENVIRONMENT

C.1. Our relationship with animals and the environment

(C 1) Humanity shares the environment with many other lifeforms – from bacteria in the soil that help recycle nutrients, to plants that produce our oxygen, to top predators who help keep the ecosystem healthy and balanced. Part of humanity's responsibility to the environment and future generations is the preservation of ecosystem biodiversity and fair, conscientious use of natural resources (ICRP, 2003) as, for example, reflected in the UN Sustainable Development Goals (UN, 2015). Since the distant past, humans have engaged in domestication of both plants and animals, which is considered by some to be a coevolutionary and mutualistic process (Zeder, 2015). Our modern responsibility thus expands from the natural environment into the care of what we might call the managed environment. The specific obligations to the natural and managed environment differ, as the resources derived from and associated values for them differ. Societally, we share responsibility for our environment, focusing on the ecosystem and natural resources as a whole. As we shift into the managed environment, responsibility narrows to country, community, and individuals. Moreover, depending on the resource provided, the level and type of care can also shift. Animals serve as companions, providing comfort or entertainment; as livestock, providing farm labour, food products, or other commodities; as workers, providing an array of non-food services from therapy to military and police operations; or as research subjects, improving fundamental understanding of biology and medicine.

(C 2) Humanity has a long and complex relationship with animals, a relationship that has changed over generations but that can also change over a single lifetime with shifting cultures, attitudes, and environments (Walsh, 2009; Shir-Vertesh, 2012). Animals have deep cultural and spiritual significance in many societies, however, there are also several sources of potential conflict (Herrmann et al., 2013). Human-wildlife conflict can result from competition for habitat and resources, which can lead to economic or even life loss for humans and ecosystem alteration, reduction in species, or even extinction for wildlife (Nyhus, 2016). Conflict also exists with domesticated animals from such sources as bites, scratches, or kicks; financial or time burden; excess noise; overpopulation or abandonment of companion animals; and spread of disease or other health impacts (e.g. allergies) (Voith, 2009; Wells et al., 2019). Regardless of these sources of conflict, animal interactions serve an important role in human survival and well-being (Herrmann et al., 2013), and consistent with the general ethical principles of respect for life, empathy, and rejection of cruelty (Warren, 1997), we have the responsibility to mitigate conflict and promote animal welfare as part of a holistic approach to sustainable development and maintenance of human health and well-being.

C.2. Radiological protection and environmental ethics

(C 3) The primary aim of the ICRP relates to protection of both humans and 'the environment' and thus implicitly includes biota other than humans. Such an aim is also based on a number of ethical considerations, although it has to be accepted that attitudes associated with protection of any particular species differ from one society to another, and from one situation or circumstance to another within any one society. The subject was first explored by the IAEA (IAEA, 2002) and then discussed further in *Publication 91* (ICRP, 2003b). In these studies a useful three-component ethical spectrum of views was identified. These views arise from philosophical debates about what has moral standing in the world and why. Essentially they may be briefly summarised as follows: anthropocentric, in which human beings are the main or only thing of moral standing, and thus the environment is of concern only as it affects humans; biocentric, in which moral standing can be, and usually is, extended to individual members of other species, and thus obligations pertaining to such individuals arise as a consequence; and ecocentric, in which moral standing can be extended to virtually everything in the environment (including physical features, such as rivers and mountains) but the focus lies more on the entirety and diversity of the ecosystem rather than, say, the moral significance of each and every individual component of it. There are, of course, considerable ranges of views within each of these three broad categories.

(C 4) The anthropocentric view is the most easily recognised and is reflected in many world religions; the other two are less easy to define. Biocentric views vary considerably, but a common feature of many of them is recognition of the moral obligations that arise from the fact that many animal species can be shown to be sentient, in that they can experience pleasure and pain. The results of these considerations are reflected in attitudes to animal 'rights' and animal 'welfare', and thus in national laws - such as those relating to experiments on animals, for whatever reason. Biological characteristics other than sentience may also be considered relevant, and some biocentric views assume that all individual living things have an inherent value and should be respected for what they are. Those with an ecocentric view, in contrast, believe that one should optimise ecosystem welfare, and although they may disagree about how to carry out such an optimisation, they agree that primacy, in moral standing, rests with ecosystems. The place of humans and the degree to which they can be considered to have special 'rights' compared with those afforded to other species and to physical components of the environment also vary. Such views can often be clearly recognised in many cultures and beliefs. It also has to be admitted that individuals may change their ethical views during their life, or when faced with different circumstances. But such views are also, and importantly, collectively reflected at social, cultural, and religious levels of society.

(C 5) The Commission therefore acknowledged (ICRP, 2007) that, in contrast to human radiological protection, the objectives of environmental protection are both complex and difficult to articulate. It did however subscribe to the global needs and efforts required to maintain biological diversity, to ensure the conservation of species, and to protect the health and status of natural habitats, communities, and ecosystems. It therefore developed a framework in order to meet these objectives by way of a practical system using a set of Reference Animals and Plants (seven animals and three plants), which included numerical approaches to their dosimetry, radiation effects, and data sets to help guide decision making for Representative Organisms under different exposure situations (ICRP, 2008, 2009, 2014, 2017).

C.3. Ethical issues in veterinary practice

(C 6) None of the above described approaches to the protection of the environment, nor that in relation to the protection of humans, clearly relates to the situation experienced in veterinary medicine. With regard to the protection of animal species in an environmental context, the emphasis is on their protection at a population level rather than at the level of individual animals (except in rare cases) and in this sense both anthropocentric and biocentric ethics may apply. Thus species are protected because of their human 'value', but they are also often protected because of biocentric concerns, and actions are therefore taken to save individual animals, or to alleviate their pain or discomfort as, for example, in the case of stranded cetaceans, and to do so if necessary by euthanasia.

(C 7) Veterinary medicine, like human medicine, is regarded as being conducted under Aesculapian (i.e. the healing arts) authority which is essentially the uniquely powerful authority vested in those practitioners that society perceives as 'healers'. It is Aesculapian authority that licenses a medical (or veterinary) practitioner to handle their patients, and to treat them in various ways. The human medicine situation is however somewhat different from that of veterinary medicine in that there are usually, but not always, two parties involved: the health professional and the patient. But in certain cases there are three: the health professional, the patient, and the patient's guardian, carer, or parent. Although it may be assumed that all of those parties who are capable of coming to a decision on what to do best are acting in the highest moral way, differences of opinion may nevertheless emerge - such as between the views of the health professional and the parent or guardian of a small child on what to do in the best interests of the child. In such cases, mechanisms usually exist such that the final decision may be made by a court of law, but the overall aim is not usually in dispute: the well-being, and thus 'good' of the patient.

(C 8) In the case of veterinary medicine there are also (usually) three relevant parties: the veterinarian, the animal patient, and the animal's owner or guardian. But considerable differences may exist between the value judgements applicable to each party: in particular, who takes the risk, who reaps the benefit, and why. This dilemma has often been central to the development of ethics within the veterinary profession.

(C 9) This development may be viewed as the combination of two different but related subjects. One is that of 'animal ethics' or what is often called 'the animal problem' that has been a matter of discussion since the days of Aristotle: it tries to tease out what the morally relevant differences are between humans and animals (e.g. Beauchamp and Frey, 2011). Essentially, if there is no difference, then how do we justify treating animals in the ways that we do; and if there is a difference, then what is it about this difference that allows us to treat animals in the way that we do? The second is essentially that of the more recent subject of animal welfare: how the lives of individual animals may be impoverished such that they suffer as a result, or are harmed; or, on the other hand, how their lives may be improved. The result is an ethic that is very similar to that of medicine, but key basic differences are also apparent, particularly with regard to the objective of preserving life. Thus although this is essentially an all-pervading one in medicine, in veterinary practice such decisions are also tempered by the different life expectancies, quality of life, or even assumed purpose in life (as in the case of livestock) of the animal in question.

(C 10) One fundamental problem has usually been that of to whom should the veterinarians' primary responsibility be: to the animal, or to the animal's owner? This question is exacerbated by the fact that, in the law of many countries, a person may hold 'property rights' over animals, thus implying that they may own animals as private goods, make use of them for economic gains, and dispose of them in a manner deemed 'fit' within the law. The veterinarian's client will, therefore, be the holder of these property rights. This view of animals as a 'property' is a source of some of the ethical dilemmas faced by veterinarians and has an effect on the vet-animal-client (owner) relationship. The owner may demand that the veterinarian opinion should be secondary, because he/she owns the animal and may thus ask the veterinarian to comply with his/her decision. This may particularly be the case with regard to livestock. Different again is recognition of the extremely strong bonding between owners and their domestic (pet or companion) animals which may create a psychological barrier between the veterinarian and the client, especially in issues connected with euthanasia. A further consideration may be the owners' willingness and ability to pay. Moreover, of note is that irrespective of the debate about duty to the animal or the owner, there is a duty of the veterinarian to protect their staff members from undue radiation exposure.

(C 11) One also has to accept that the world of veterinary practice is fairly dynamic. Private practices are run essentially as businesses, and there is thus competition amongst private practices and between those that are run 'for profit' and those that are not. These realities are likely to increase friction and therefore ethical dilemmas amongst veterinarians because some may adopt methods to undercut the 'competition' or behave opportunistically toward their clients. In the long run, however, it may well be considered that 'fair competition' is good for the client.

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At its meeting in Québec City, Canada, in April 2018, the Main Commission of ICRP approved the formation of Task Group 110, reporting to Committees 3 and 4, to advise the Main Commission on radiological protection aspects involved in the applications of ionising radiation in veterinary medicine. As such, this includes treatment of occupational and public exposure of humans as it relates to delivery of veterinary care, and radiological protection considerations for the animals receiving such care. The Task Group is to also consider the risks resulting from contamination of the environment from the applications of nuclear medicine in veterinary medicine, along with the ethical considerations underlying various types of veterinary practice, and the ethics applied to protection of animals and plants in the environment.

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