Radiological Protection of the Animal Patient

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Why should we care about radiological protection of the animal patient?

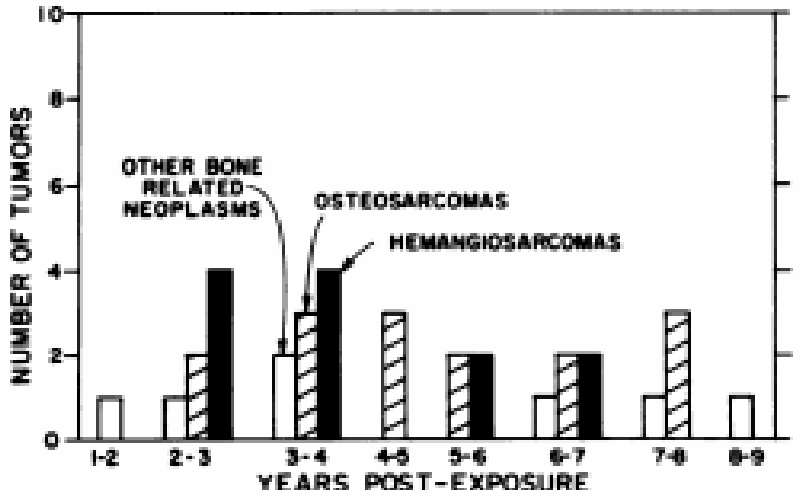
ICRP 138 Core and Procedural Values	Additional interpretation	Description
Beneficence/ Non-maleficence	**Animal welfare**	Promotion of **health and welfare** along with **minimization of suffering** in animal care.
Prudence	Sustainable development	Acting with precaution particularly when decisions might affect future generations.
Justice	Solidarity	Employing the co-expertise process such that outcomes are as fair, equitable, and balanced as possible.
Dignity	**Reverence for life**	Recognition that both humans and **other living things** have **value and importance.**
Accountability	**Stewardship**	**Responsible** use or management of **things entrusted to one's care**, whether pets, livestock, land, resources, or even medical records or other personal information.
Transparency	**Respect for autonomy**	Open and honest communication in support of the **right of individuals** to **know relevant risks and benefits** in order to make informed decisions.
Inclusiveness	Empathy	Meaningful engagement with others and appreciation of needs, challenges, and values for mutually agreeable outcomes.

Common misconceptions

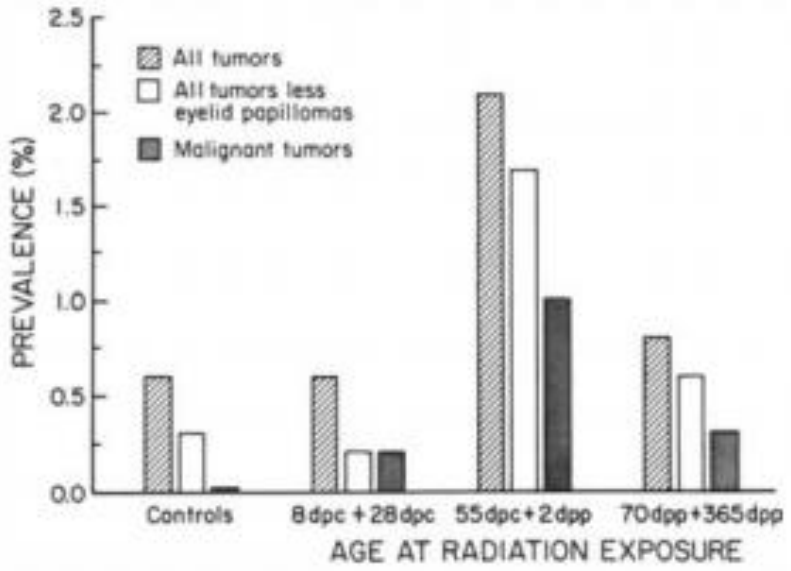
- **Stochastic effects:**
  - “Animals don’t live long enough to get radiation induced cancers”
- **Tissue reactions (deterministic effects):**
  - “Radiation doses in veterinary medicine aren’t high enough to produce tissue effects”

Animals *do* get radiation induced cancers!

- **Cancer patterns in mammals are similar and relative to life span**
  - Shorter latency period for animals with shorter life span
- **Large number of studies investigating radiation carcinogenesis in experimental animals**
  - Clearly demonstrating radiation carcinogenesis in these animals
  - Including large canine studies
    - Internal and external exposure
    - Including in utero and neonatal exposure



Benjamin et al. 1975 Can Res



Benjamin et al. 1986 JNCI

Radiation induced cancer in a clinical setting

- **Radiation induced osteosarcomas in dogs treated with radiation therapy**
- **Gillette et al. 1990:**
  - 3/87 dogs irradiated for soft tissue sarcomas developed osteosarcomas within the radiation field
    - In atypical locations for primary OSA
  - Latency period: 1.7 to 3.2 years
    - Only 22/87 dogs survived long enough to be at risk for radiation induced tumours
  - Also included study with experimental intraoperative radiotherapy and external beam radiotherapy of normal dogs
    - 7/27 dogs developed osteosarcoma

Osteosarcoma in a dog 5 years after treatment for mast cell tumour
Pentreath et al. 2020

High dose procedures are increasingly adopted in veterinary practice

- **Radiation therapy**
  - External beam (EBRT)
    - Orthovoltage
    - Co-60
    - Linear accelerators
      - Intensity modulated radiotherapy (IMRT)
      - Stereotactic radiotherapy (SRT)
  - Brachytherapy
  - Radionuclide therapy

- **Interventional radiology**
  - Vascular
  - Urinary
  - Respiratory
  - Gastrointestinal
  - Cardiac
  - Orthopaedic

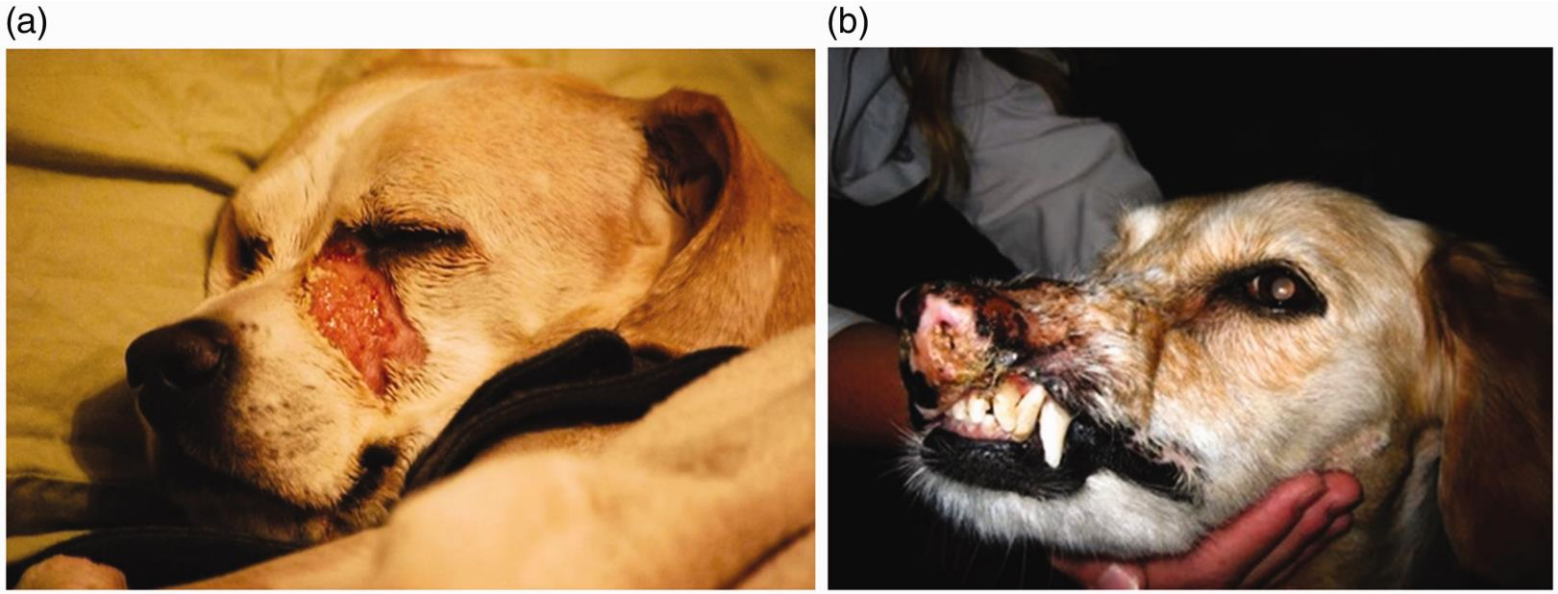
Hersch-Boyle et al. 2019 AJVR:

- Fluoroscopy time: 0.02 – 85.12 minutes
- Radiation exposure: 0.14 – 617.51 mGy

Tissue effects do occur in radiotherapy

- **Both acute and late effects are seen**

Lekuotrichia 3 months after intensity modulated radiotherapy for sinonasal neoplasia
ICRP 153



a) Radiation treatment burn 1 week after tomotherapy for nasal carcinoma
b) Fibrosis in a dog 3 years after hypofractionated radiotherapy for mast cell tumour of the lip
Pentreath et al. 2020

And accidents do also occur!

- But few cases are reported
  - Variable local and national requirements for reporting incidents involving dose errors affecting the veterinary patient only
- Arkans et al. 2017:
  - An SRT plan was created for a canine patient in August, but not delivered at the time, as owners opted for medical management
  - On disease progression, a new treatment plan, consisting of single fraction SRT, followed by full course IMRT was created in November
  - The single fraction SRT was delivered uneventfully
  - At the time of the first IMRT fraction, the original SRT plan from August was erroneously loaded and the first fraction of this plan delivered instead of the first fraction of the IMRT plan
    - Approx. 370% more dose delivered than intended for that day (10 Gy vs 2.7 Gy), majority to the tumour

Unique aspects of veterinary practice

Competence

- Limited radiation protection training in veterinary education
- Image acquisition and interpretation often performed by non-specialized staff
- High dose diagnostic as well as radiotherapy procedures may be performed by practitioners without accredited and certified specialist training
- Lack of involvement of medical physicists

Equipment

- Second-hand equipment from human medicine used without adequate QA
- Specialty veterinary equipment falling under industrial rather than medical standards

Regulation/Guidelines

- Lack of regulatory harmonization
- Lack of guards against self-referral and “self”-presentation
- Lack of ”referral guidelines”/”appropriateness criteria” supporting justification

How to improve radiation protection for animal patients?

Ensure all radiological procedures are

- Justified
- Optimized

Level of justification	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** the **diagnosis or treatment** of a **defined group of animal 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 animal patient**

Justification – benefits and risks

- **Kelsey et al. 1998: "Dogs should be exposed to radiation only when the expected benefits will outweigh the risks"**

	Benefits	Risks
Animals	Improved diagnosis and treatment Animal suited for intended use Early detection of subclinical disease Improved population health	Stochastic effects Tissue reactions Misdiagnosis or inappropriate treatment
Veterinary staff	Professional satisfaction Customer satisfaction Financial revenue	Stochastic effects Tissue reactions
Owners/handlers	Emotional and economic benefits of improved health of their animals	Stochastic effects
General public, society and environment	Control of zoonotic disease Economic benefits of healthy working and production animal populations	Environmental contamination

Justification – how to ensure it?

- **Education and training**
  - Awareness of doses and associated risks from various radiological procedures
  - Ability to perform risk communication with owners and handlers
- **Decision support tools (referral guidelines/appropriateness criteria)**
  - Should be easily accessible, free of charge, and easy to use
  - Need to be developed collaboratively by national/international professional veterinary radiological societies, veterinary professional bodies, animal health and regulatory authorities
    - Requires substantial commitment of ***time and resources*** to ***creation and updates***
- **Comprehensive radiology requests**
  - Should contain sufficient clinical information that radiologist or internal/external auditor can assess whether a particular examination is justified
- **Adoption of new types of radiological equipment**
  - Potential implication for radiological protection should be assessed

Justification of non-medically indicated investigations

- **Imaging of asymptomatic animals for purposes other than medical diagnosis or treatment**
  - Hip and elbow dysplasia radiographic screening programmes in dogs
  - Standardized radiographic examinations for stallion approval
  - Presale radiographic examinations of racehorses, competition and pleasure horses
  - Radiographic examinations for insurance purposes
- **May not always be consistent with current clinical evidence**
- **Level 2 justification thus particularly important**
  - Procedure should be suitable for detection of the condition in question and for screening a large number of animals
  - Should be a demonstrable relationship between imaging findings and the goal of the screening
  - Appropriateness criteria may be developed

Optimization

- **Always aimed at achieving the best level of protection under the prevailing circumstances through an ongoing, iterative process (ICRP 2007)**
- **Increased life span and increased prevalence and frequency of radiological examination in companion animals increases the need for optimization**
- **Adjust imaging exposure parameters or adapt activity of administered radiopharmaceuticals so that required clinical effect is obtained the the lowest possible radiation dose**
  - Reducing the dose to the animals will often also reduce dose to humans
  - Diagnostic or therapeutic quality must however be maintained
    - Optimization ≠ Dose minimization
      - Underdosage may result in a non-diagnostic study that has to be repeated, or clinically relevant lesions may be missed

Optimization in general

- **Appropriate design and construction of installations**
- **Careful selection of equipment**
- **Day-to-day strategies**
  - Education and training of staff
  - Clarity regarding roles and responsibilities
  - Routine performance tests of equipment
  - Systematic application of procedural rules
- **Diagnostic reference levels (DRLs) currently not available in veterinary medicine**
- **Optimization must also take into account other factors, such as**
  - Other occupational hazards facing the veterinary staff
  - Clinical condition of the animal

Optimization in veterinary radiology

- **Ensure equipment is fit-for-purpose**
  - Equipment designed specifically for veterinary use may conform only to industrial standards, may be insufficient from a radiological protection perspective
    - E.g., reduced shielding in portable radiographic equipment
- **Limit the radiographic views/body areas imaged in CT to those necessary for a given diagnostic protocol**
  - Referral guidelines/appropriateness criteria and standard protocols for common situations would aid greatly in veterinary practice
- **Avoid repeat examinations that do not given a clinical benefit**
- **Develop technique charts for the range of animal sized relevant to the facility**
- **Limit the exposed tissue volume to what is relevant for the clinical case**
  - Collimation (radiography, fluoroscopy) and scan length limitation (CT)

More dosimetric data are needed!

- **Particularly for potentially high-dose procedures**
  - Interventional radiology
  - Fluoroscopically guided surgical procedures
  - CT interventional procedures
  - Dynamic CT examinations
- **Systematic reporting of dose descriptors for clinically relevant protocols**
  - E.g., dose area product (DAP) and CT dose index
  - Necessary to compare protocols within and between institutions
- **Relationships between dose descriptors, organ doses, and associated radiation risks must be determined for veterinary medicine**
  - Animal patient-based voxel phantoms
  - Monte Carlo simulations

Optimization in veterinary radiotherapy

- **Optimization crucial in all radiotherapy**
  - High doses to the target volume to achieve desired therapeutic effect while keeping the exposure of other tissues and organs as low as reasonably achievable
    - Avoid deterministic effects as far as possible
    - Limit the overall exposure of healthy tissues to reduce probability of second cancers
- **Complex and high-risk procedures that should only be performed by veterinarians with extensive training and education in radiological protection**
  - Specialists, e.g., diplomates of specialty education and training programmes
  - Providers of such programmes should ensure radiological protection is an integrated part of their curricula

Additional data is also required in radiotherapy

- **Completeness of reporting of treatment planning must be ensured**
  - Radiation dose, treatment delivery, quality assurance, adjunctive therapies
  - Currently insufficient in a large portion of published veterinary studies
    - Keyerleber et al. (2012): None of the studies had a level of completeness consistent with ICRU guidelines, only 24% reported more than 50% of items evaluated
- **Variability in contouring of target volumes and normal tissues must be addressed**
  - May contribute to different tumour response and normal tissue toxicity in a given patient (Christensen et al. 2016)
- **Variations exist in fractionated protocols, even for curative intent and the same condition**
- **Prospective clinical trials needed in veterinary radiation oncology to assess clinical outcomes**

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Thank you for your attention!

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