REVIEW ARTICLE

VETERINARY NUCLEAR MEDICINE: A LOOK INTO THE FUTURE

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ABSTRACT

The use of nuclear energy in veterinary medicine has been increasing over the last two decades. It mirrors the use in human health, but lags behind significantly. It is thought that animals are capable of undergoing almost any diagnostic or therapeutic procedure from human medicine.

Strict rules about the use of nuclear energy in veterinary medicine are governed by the national authorities, and harmonized by the world leading authority in the field, the International Atomic Energy Agency (IAEA).

Veterinary nuclear medicine has a clear methodology based on human medicine. Specificities relate to animals as patients, their lack of conscious cooperation, radiation safety measures in the light of animals'free movement, scarcety in trained staff and interest in referring at the side of veterinarians. Of primary concern remain the financial considerations, directly affecting the availability of veterinary nuclear services. Developed countries top the lists with services offered in veterinary nuclear medicine.

Veterinary nuclear imaging can be preclinical for research purposes and clinical for diagnostic purposes. Isotopes of higher emission energies can be applied for therapeutic purposes to treat diseases. Such a combined use of isotopes for diagnostic and therapy gives a rise to the new field of theranostics. Nuclear images are created by injecting radioactive isotopes into animals, which then accumulate in the organs, depicting their morphology or function. Imaging is made by a scintillation gamma camera. Nuclear images are called nuclear scans, and the technique is called scintigraphy. Most commonly used radioactive isotope for diagnostic imaging is technetium Tc-99m, and for treatment iodine I-131.Scintigraphies most commonly performed on animals are thyroid, bone, liver and renal, all indicated in specific clinical scenarios.

Number of both production and companion animals in the world is increasing. Consequently, demand for veterinary services has also been increasing, so that standard animal care needs constant improvement. That is why a need for more and novel diagnostic and therapeutic procedures, including the nuclear ones, will become more evident.

Novel trends in veterinary nuclear medicine follow the trends in human medicine and are rapidly expanding. They include both research and clinical veterinary medicine.

Keywords: Imaging, isotopes, scintigraphy, veterinary nuclear medicine

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INTRODUCTION

Nuclear energy has been in use for medical purposes for more than seventy years now. Non-clinical and clinical applications have been constantly broadening, reaching molecular imaging, which is defined by the Society of Nuclear Medicine and Molecular Imaging (SNMMI) as the visualization, characterization, and measurement of normal as well as abnormal cellular processes in living systems at the molecular or genetic level rather than at the anatomic level. Nuclear energy can be used for diagnostic and therapeutic purposes. Recent developments based on novel isotopes have given rise to so-called theranostics, a term coined from therapy and diagnostics in order to describe the combination of using one isotope to diagnose the second one to treat a disease because of their different emission energies (Ziesmann, et al., 2006).

The use of isotopes in veterinary medicine has a clear methodology, which practically mirrors the use in human medicine. However, veterinary nuclear medicine significantly lags behind, primarily due to high costs of setting up and organizational issues related to maintenance of veterinary nuclear practice. Also, very strict rules and regulations must be followed when handling radioactive materials. That is why the availability of nuclear procedures for animals is limited, and roughly reflects the level of development of a country (IAEA, 2021).

Animals are mostly considered to be apt to stand mostly any diagnostic or therapeutic procedure as humans. The growing number of animals acquired and taken care of for production or companion purpose emphasizes the need for better veterinary care, including the state-of-art diagnostic modalities and therapeutic options available in veterinary practice. Over the last two decades, the use of nuclear energy in veterinary medicine has been increasing (IAEA, 2021).

Basic principles

In order for an image to be obtained in veterinary nuclear medicine, an animal has to be dosed with a radioactive isotope inserted into the body. While prepared for application, the isotopes are bound to specific pharmaceuticals, and such radiopharmaceuticals are delivered via the blood stream to the organs they have affinity for. When the isotope is in the blood stream, the animal and its excretions become radioactive for some time. In this way, animals become the radiation source, not the equipment, unlike in radiological techniques (Ziesmann et al., 2006; Lattimer, 2019).

Since they are radioactive, isotopes are unstable and subject to decay with emission of gamma photons and particles. Photons leave the animal body and get registered by a scintillation detector of a gamma camera (Figure 1,2), a basic of equipment at any nuclear department. Once the photons are registered, an image can be created and displayed by computer processing.

Nuclear images are called nuclear scans, and the technique is called scintigraphy (Ziesmann et al., 2006).

Most commonly used isotope for diagnostic purposes is radioactive technetium Tc-99m, which is produced in molibdenum-technetium generators (Mo99 – Tc99m), readily available from commercial suppliers. Most commonly used isotope for therapeutic purposes is iodine I-131 produced in nuclear reactors. Repetitive delivery of isotopes is costly, and requires good organization and planning in advance (Ziesmann et al., 2006; Balogh et al., 1999).

Nuclear scans depict morphology of the organs (such as size, shape, contours) and pathologic lesions on static images acquired over a short time, but also their function in a series of sequential, faster dynamic images (Ziesmann et al., 2006).

Nuclear imaging is considered to be safe, non-invasive and easily reproducible. Main advantage is the high sensitivity for detecting early disease, as it works on cellular or subcellular level. Low doses of radiation make repated imaging possible (Ziesmann, et al., 2006; Lattimer, 2019).

Once applied to the animal, radiopharmaceuticals metabolize, and in parallel with radioactive decay, they eliminate in the urine, feces, sweat and saliva. In this way, radioactive isotopes may reach the environment and expose animals' owners, household members, handlers and other in-mate animals to radiation (Lattimer, 2019). Even though such doses are low, they should be further minimized, as recommended by the legislators. Small animals such as dogs and cats are imaged for diagnostic purposes on an outpatient basis, and their disharge is followed by hygienic measures applied by the owners and handlers (e.g. wearing rubber gloves when in contact with the excretions). Horses are not discharged until the following day as they are not considered to be radioactive 24 hours after scintigraphy (Lattimer, 2019, Winter et al., 2010). When radioiodine is applied for therapetic purposes, animals are hospitalized for a few days, and once home, they need to be isolated for two weeks. No contact with other animals, pregnant women or children is recommended during this time (Animal Imaging, 2021).

Equipment

The basic equipment for nuclear imaging is a gamma camera (Figure 1,2). Every gamma camera has one or more scintillation detectors, which detect radioactivity in animal body. Detectors can be fixed or rotating in order to register as many radioactive events as possible at the same time. In veterinary nuclear practice, the size of a gamma camera is conditioned by the size of the animal imaged. Small laboratory animals such as mice require smaller gamma cameras with small detectors, while the clinical imaging of large animals such as horses requires detectors of the size used in human medicine (Figure 1,2) (IAEA, 2021; Balogh et al., 1999).

Latest nuclear imaging equipment is hybrid, which means two different machines are combined into one, representing the top imaging technologies. Such machines are: PET/CT (positron emission tomography/ computed tomography), SPECT/CT (single-photon emission computed tomography/ computed tomography) and PET/MRI (positron emission tomography/ magnetic resonance imaging). Hybrid imaging provides cross-sectional images and has higher spatial resolution and better sensitivity then stand-alone machines. Hybrid imaging is widely used in human medicine now, but rather scarce in veterinary practice. Back in 2019, only two centers worldwide offered PET for animals. It is still mostly used for research purposes with the main advantage of a plethora of diagnostic information obtained during one single imaging (Aguiar, et al., 2014; Nelson, 1996; Spriet, 2019).

The procurement of veterinary nuclear equipment should not be an issue as it is widely available from different vendors on the markets. Brand new state-of-art equipment is available as well as second-hand equipment, which is very often used in veterinary nuclear practice. Usually, the old hospital cameras are dismantled and installed in veterinary departments. Such refurbished cameras reduce costs of setting up a nuclear department. Alternatively, parts of different old cameras are used to build "new" second-hand cameras (Lattimer, 2019; Spriet, 2019; Aguiar, et al., 2014).

Figure 1 Equine bone scintigraphy with a gamma camera. Note the detector registering radioactivity in horse is closest to the ribs (Source: Rossdales Veterinary Surgeons, UK, 2021)

Figure 2 Equine bone scintigraphy. Note the detector closest to the left front foot, a region of interest for a spot view (Source:California Equine Orthopedics, USA, 2021)

Preclinical use

Most common use in the preclinical setting is in a pharmaceutical field in relation to drug and vaccine development and studies of their effects, all before the clinical trials. The other application is a wide spectrum of biomedical reasearch, where physiologic or pathologic processes are investigated. Animal models are used because of their similarities to humans from the anatomic and physiologic point of view, but also because human diseases often affect animals, and are transmissable between the species (Vanhove, et al., 2015).

Clinical use in veterinary medicine

Referring veterinarians are acquainted with nuclear imaging techniques. They make clinical questions that can be answered with this type of imaging. Nuclear imaging is indicated over radiological for its higher sensitivity for specific indications and in certain clinical scenarios.

Most commonly imaged organs are: thyroid gland, bones, kidneys and liver for portosystemic shunts. Also, brain, lungs and heart as well as tumors and inflammations/infections can be imaged (Lattimer, 2019; Baloghet al., 1999).

Thyroid scan

In suspected hyperthyroidism, thyroid scans are obtained using technetium Tc-99m-pertechnetate injected intravenously. It is most often performed in cats and dogs.Hyperfunctional thyroid tissue accumulates more Tc-99m-pertechnetate then the background, so the “hot spot“ in the neck is diagnosed on the static images (Figure 3 A,B,C)

(Peterson and Broome, 2015).

Once hyperthyroidism is diagnosed, radiaoctive iodine I-131 could be administered for therapeutic purposes. Once applied orally, it accumulates in thyroid cells, reverse their hyperfunctionality by irradiating them and restore an euthyroid state (Ziesmann et al., 2006).

Thyroid scan is also indicated in thyroid cancer,when the whole body is imaged looking for metastases. Metastatic foci are also detected as focal "hot spots" (Figure 3D). Thyroid cancer metastases may be treated with iodine-131, which is applied upon the diagnostic imaging with techentium-99m pertechnetate. Such use of technetium-99m and ioidine I-131 in benign and malignant thyroid diseases is an excellent example of theranostics in veterinary clinical practice (Peterson and Broome, 2015).

Liver scan

Liver scan is indicated when portosystemic shunt is suspected, and the ultrasound fails to diagnose.It commonly occurs in dogs. Since the portosystemic shunt is an abnormal blood vessel that exists between the portal and systemic venous systems bypassing the liver, the radiopharmaceutical carried from the portal circulation must be followed. A hepatic agent such as Tc-99m mebrofenin is injected into the spleen with ultrasound guidance, and its pathway from the spleen is followed on dynamic images (Figure 4). In case of a shunt, no isotope is registered in the liver, only in the heart and lungs via the systemic circulation (Tsai, 2021).

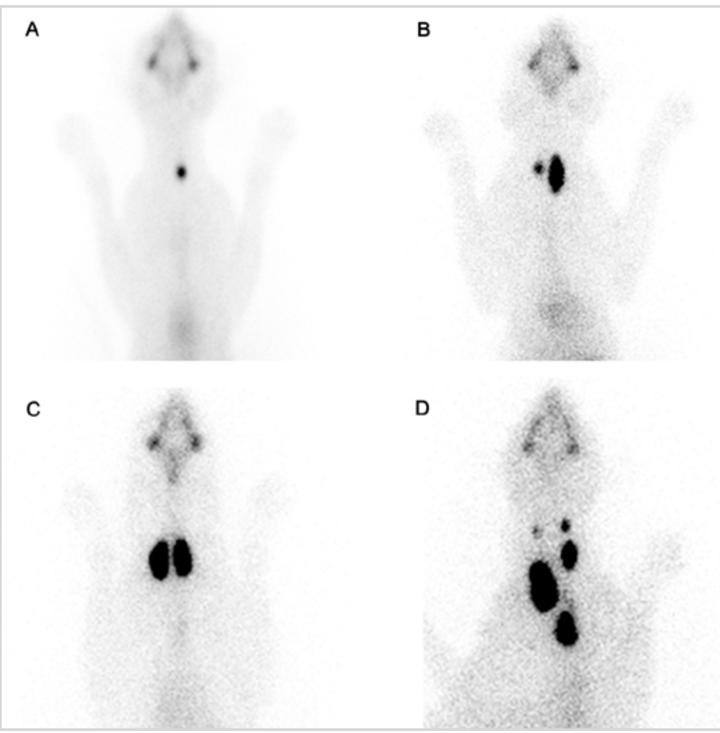

Figure 3 (A, B, C, D) Feline thyroid scan. Increased accumulation of Tc-99m pertechnetate as focal "hot spots" in four hyperthyroid cats (A) Increased accumulation in the left lobe(B) Assymetrically increased accumulation in both lobes (C)Symmetrically increased accumulation in both lobes (D) Multifocal disease suggestive of ectopic thyroid tissue or metastases of the thyroid cancer (Source: Peterson and Broome, 2015)

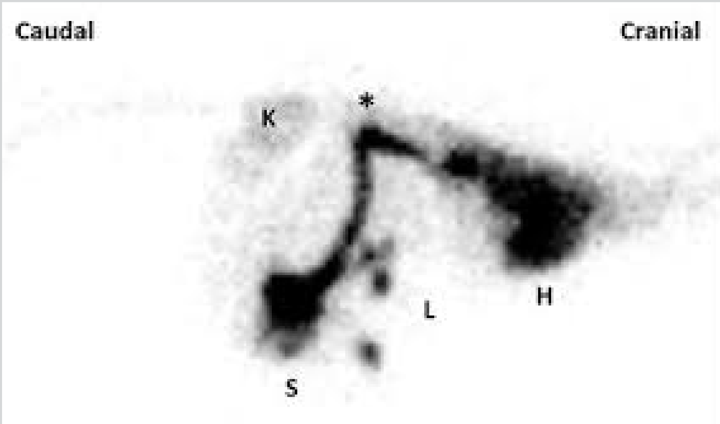

Figure 4 Scintigraphic image of portosystemic shunt in a dog. The image demonstrates movement of the isotope from the spleen (S) via a shunt vessel (asterisk) to systemic circulation, the heart (H) and kidney (K), bypassing the liver (L) (Source: Tsai, 2021)

Bone scan

Bone scan is mostly performed in horses and dogs. It is indicated in suspected occult fractures that go undiagnosed on radiological studies. Animals usually present with lameness, reduced ability to perform movements and behavioral changes. Bone scan in fractures is pathologic before the x-rays because it reflects metabolic cellular activity of osteoblasts, which occurs before the structural changes appear on the bone. Fractures present as focal „hot spots“ characterized by increased accumulation of the isotope caused by increased osteoblastic activity (Figure 5 A,B). As bone repair progresses, osteoblastic activity tends to decrease, and isotope accumulation decreases as the callus is formed. So, the bone scan can also suggest the timing of fracture and the phase of bone repair (Ziesmann et al., 2006; Simpson, 2021).

Imaging is performed 3 hours after the injection of a bone agent such as Tc-99m-MDP (methylene diphosphonate).Whole body or spot images are made, and sometimes incidental findings in distant body regions are detected (Ziesmann et al., 2006; Schwarz et al., 2004).

Clinically, bone scan is indicated in chronic lameness, intermittent lameness, multiple limb lameness when the entire skeleton is surveyed, and back or pelvis problems of different intensity. These signs can be attributted to bone, but also joint pathology. That is why acute or chronic joint diseases are also an indication for bone scan. Arthritis is demonstrated as focal „hot spots“ with different intensity of isotope accumulation (Figure 6), which depends on the stage of inflammation (Schwarz et al., 2004; Simpson, 2021).

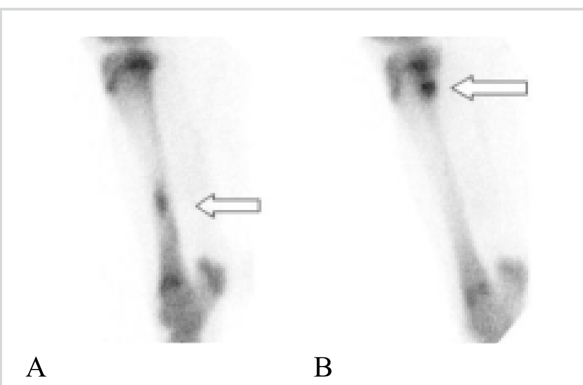

Figure 5 (A,B) Bone scan in horse (spot views).Tibial stress fractures are visualized as focal “hot spots“ indicating fractures in a racehorse (arrows) (Source: Simpson, 2021)

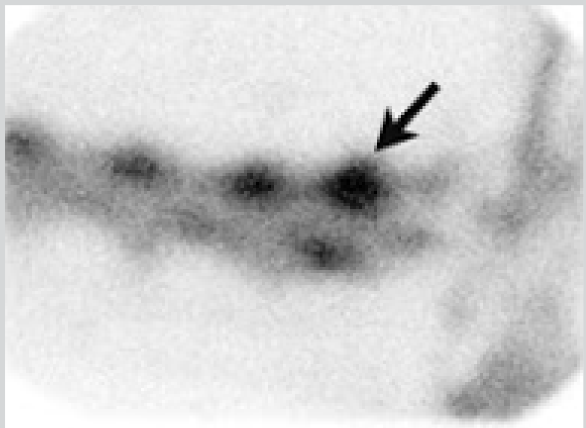

Figure 6 Bone scan in horse (spot view). Arthritis of a facet joint is visualized as focal "hot spot" (arrow), more intense than in the neighboring joints (Source: California Equine Orthopedics, USA, 2021)

Bone scan is also indicated in primary bone tumors (such as osteosarcoma) and bone metastases, which stimulate osteoblastic activity in the affected bone (Figure 7). On the contrary, when bone lesions are osteoclastic, they present as "cold" areas without isotope accumulation, but usually with the rim of increased osteoblastic activity that facilatates diagnosis (Ziesmann et al., 2006; Balogh et al., 1999).

Renal scan

Renal scan is the most common nuclear imaging in cats and dogs (Figure 8). It is recommended in impaired renal function and obstructive uropathies. Renal scintigraphyis performed by injecting Tc-99m-DTPA (diethylentriaminepentaacetic acid) or Tc-99m-MAG3 (mercaptoacetyltriglycine), which are glomerular and tubular agents, respectively. Once injected intravenously, a series of dynamic images is made as the radiopharmaceutical is taken up from the blood by the kidneys and eliminated via the collecting system (Hecht et al., 2008; Ziesmann et al., 2006).

The results of renal scintigraphy are used to asses the renal flow, function of the renal parenchyma and the collecting system. Since the clearance from

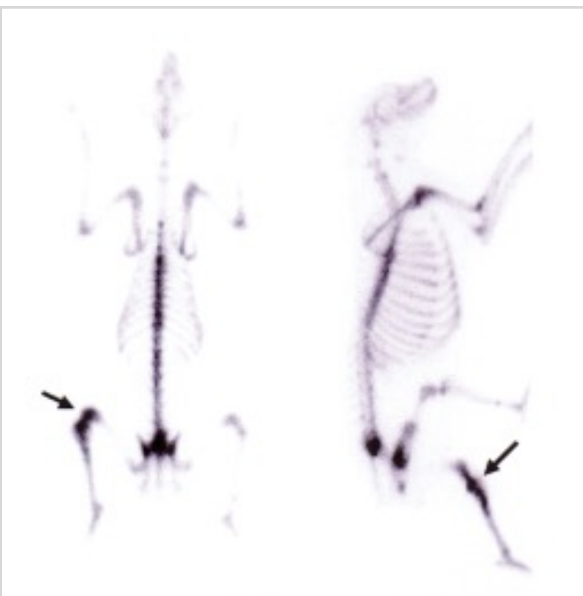

Figure 7 Bone scan in dog (total body). Note focally increased accumulation of Tc-99m MDP in the left knee consistent with primary osteosarcoma (arrow). No metastases are detected elsewhere (Source: Balogh, et al.,1999)

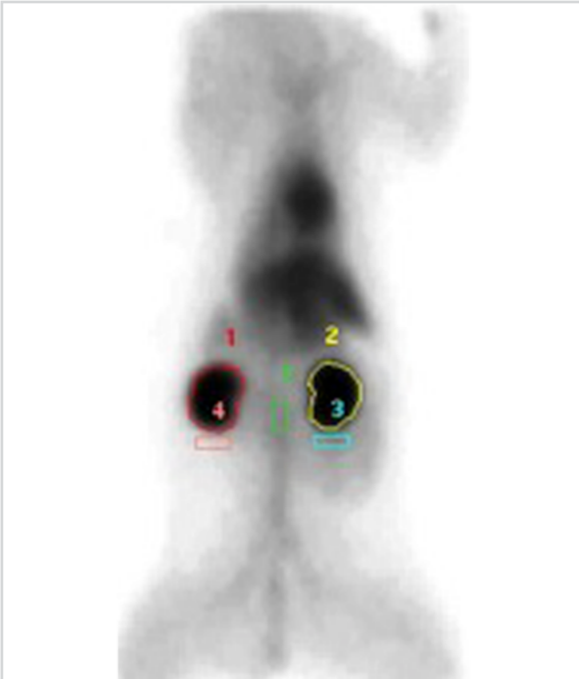

Figure 8 Renal scintigraphy in a cat imaged with Tc-99m-MAG3. Summed dynamic dorsal images show both kidneys as regions of interest (1,2) and backgrounds, including the aorta (rectangulars) (Source: Stock, et al., 2016)

the blood plasma is a function of the glomerular filtration rate (GFR), renal scintigraphy can be used to assess real-time GFR, in particular before nephrectomy (Hecht, et al., 2008; Krawiec, et al., 1988).

Novel Trends

Hybrid imaging such as PET/CT has been emerging in the diagnostic field. Its ability to depict both structural and metabolic changes by CT and PET featuring, respectively, opens up new possibilities for detection of subtle pathologic processes that would otherwise remain undiagnosed. So far, PET for animals has been mostly used for research purposes, but also clinically, and that in equine practice, particularly for racehorses imaging.

Radiopharmaeceuticals used for such purposes are 18F-sodium fluoride (18F-NaF) and 18F-fluodeoxyglucose (18F-FDG). 18F-NaF is considered to be a marker of bone remodelling and 18F-FDG a marker of glucose consumption. In this way, they demonstrate not only the lesions but also the timing of lesions accruing marked by the intensity of radiopharmaceutical acummulation, i.e. acute vs. chronic (Spriet, 2019). In clinical practice, PET can aid diagnosis in cases of bone pain manifested by lameness, limb sparing or poor performance in general. At present, the research is underway to evaluate the role of 18F-FDG PET in equine tendon assessment and different enthesopathies (Spriet, 2019). Also, currently studied with 18F-FDG PET is laminitis in the attempts to distinguish acute from chronic forms and guide treatment (Spriet, 2019). In the previous research, 18F-NaF PET succeded in confirming a specific enthesopathy in lame horses associated with foot pain by demonstrating a focally increased acummulation of 18F-NaF, which could precisely localize the histological changes proven post mortem (Norvall et al., 2021).

PET is also being used in research of stem cell tracking in tendinopathies of horses. The advantage of this technique is in sucessful labeling of mesenchymal stem cells with 18F-FDG followed by their precise localization (Spriet, 2019). Such methodology is considered an improvement in sensitivity compared to the previously used tehnetium Tc-99m- HMPAO (hexamethylpropylene amineoxime) for labeling and conventional scintigraphy with gamma camera for imaging. Nuclear imaging enables tracking of bone marrow mesenchymal stem cells (BMMSC) used for treatment of tendon and ligament injuries in horses (Dudhia et al., 2015).

Improved sensitivity of 18F-NaF is due to higher energy of photons involved in radioactive decay of PET radiopharmaceuticals. The idea of radioactive isotope-labeling of mesenchymal stem cells prior to injecting them to a horse makes them easy to track in a timely-related fashion. The intensity of focal acummulation of radiopharmaceutical is proportional to the number of labeled mesenchymal cells, and when corrected for time and radioactive decay gives an estimate of number of the cells on site. Cell-labeling and cell-tracking with nuclear imaging are powerful tools in medically advanced treatment with stem cells. Such treatments may be applied in other diseases, too, thus opening the doors for new research (Dudhia et al., 2015).

Given the versatility of biomarkers and metabolic pathways as well as extensive pathology, the field of veterinary nuclear research will be expanding. The results could then be used for diagnostic and therapeutic purposes pending the local availability of logistics.

Legislation and Radiation Safety

International Atomic Energy Agency (IAEA) remains the world authority in ensuring the general framework for the use of radioactive materials for health purposes. According to its Statute, "the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards". Only recently, the IAEA has released a new Safety Report for veterinary practictioners using radiation (2021) and for national regulatory bodies in order to provide recommendations and help them carry out their work safely (IAEA, 2021).

National legal framework is set by the State Regulatory Agency for Radiation and Nuclear Safety of Bosnia and Herzegovina (Državna regulatorna agencija za radijacijsku i nuklearnu sigurnost Bosne i Hercegovine) with the following documents: Act on Radiation and Nuclear Safety in Bosnia and Herzegovina, (2021) and Law on Liability for Nuclear Damage (2021), (State Regulatory Agency for Radiation and Nuclear Safety of Bosnia and Herzegovina).

Concerning the use of nuclear energy in veterinary medicine, common standpoint of the IAEA and the State Regulatory Agency is that the same rules and regulations as in human nuclear medicine should apply. Some specificities of veterinary nuclear medicine must be taken into consideration, such as the lack of conscious cooperation at the side of animals and strict control over them, temporary confinement or isolation of animals from the general public after nuclear procedures, adjustments of doses for diagnostic or therapeutic purposes, use of anaesthesia, adjustments of equipment because of the patients' size, etc. (IAEA, 2021).

From the point of radiation safety, the basic ALARA (as low as reasonably achievable) principle should be applied. It implies the exposure to ionizing radiation should be as low as achievable in order to fulfill the required goal, that is, obtaining an interpretable diagnostic image or treatment of a disease. Recommended doses of radioactive isotopes for diagnostic and therapeutic purposes are harmless for animals. Veterinary staff handling the materials and animals is obliged to follow the basic radiation protection principles (reduce time of exposure, keep the distance and use personal protective equipment like gloves, sleeves and aprons (IAEA, 2021; State Regulatory Agency for Radiation and Nuclear Safety of Bosnia and Herzegovina, 2021). Academic programs and trained and certified staff are required for veterinary nuclear medicine. Where available, these special trainings are offered within the veterinary radiology residency programs. In the United States, veterinary radiologists who also perform nuclear medicine studies are members of The American College of Veterinary Radiology (ACVR), and undergo post-graduate training in a three or four-year residency program, followed by examination. ACVR has the Society of Veterinary Nuclear Medicine under its umbrella (SVNM/ ACVR) (ACVR, 2021; ECVDI, 2021).

In the EU, the main governing body is the European College of Veterinary Diagnostic Imaging (ECVDI) granting specialist status in veterinary diagnostic imaging in the European Union. According to ECVDI, diagnostic imaging is defined as the specialty of "diagnosis with the aid of images representing anatomy, physiology and pathology of the body, predominantly by radiology and ultrasonography, but also by nuclear medicine, computed tomography and magnetic resonance imaging" (ACVR, 2021; ECVDI 2021).

CONCLUSION

Nuclear imaging and treatment are used in modern veterinary medicine. Availability of veterinary nuclear applications is limited though, and mostly offered in developed countries. It is used in the preclinical settings for research and clinical settings in veterinary clinical practice. Nuclear studies are considered to be safe, non-invasive and reproducible. Animals do not incur pain for nuclear procedures.

Primary issue in setting a veterinary nuclear practice is of the financial nature. Organization and workflow are complex, and must be realized in accordance with the regulations stipulated by the national governing bodies and the IAEA.

Animal nuclear imaging is costly, not only because of sophisticated equipment, but also because of the entire logistics chain that needs to be set in function, as there is a repetitive need for procurement of the isotopes. Bosnia and Herzegovina has an access to the isotopes' supply markets, and is considered to be a small consumer on the world scale.

Training of veterinary staff is time-consuming, and motivation and dedication are required. Veterinary practitioners need to be familiar with the indications for nuclear studies and request them with precise clinical questions to be answered.

Number of production and companion animals has been increasing worldwide. Also, general healthcare standards are constantly being raised.

Figure 9 Image courtesy of the Foundation"Land of Friendship and Peace"/ Fondation "Terres d'amitié et de paix"/ Fondacija„Zemlja prijateljstva i mira",Rakovica, Canton Sarajevo, Bosnia and Herzegovina, 2021

That is why there are more and more tools available to veterinary practitioners, and veterinary nuclear medicine is definitely one of them. Even though it might be a closer or distant future, it is a future, after all.

Image illustrates a riding unit of the Foundation (Figure 9), the first equine and recreational center in our country that has largely popularized equestrian sport in Bosnia and Herzegovina through its numerous activities. Normal aging as well as performance stresses may predispose these horses to pathologic processes for which nuclear veterinary medicine might be able to provide information about.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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VETERINARSKA NUKLEARNA MEDICINA: POGLED U BUDUĆNOST

SAŽETAK

Nuklearna energija se u posljednje dvije decenije sve više koristi u veterinarskoj medicini. Iako njena upotreba oslikava korištenje u humanoj medicini, znatno zaostaje za njom. Smatra se da životinje mogu biti podvrgnute bilo kojoj dijagnostičkoj ili terapijskoj proceduri koja se koristi u humanoj medicini.

Državna regulatorna tijela propisuju stroga pravila o korištenju nuklearne energije u veterinarskoj medicini koja su harmonizirana od svjetskog autoriteta u tom polju, Međunarodne agencije za atomsku energiju (IAEA).

Veterinarska nuklearna medicina primjenjuje jasnu metodologiju temeljenu na humanoj medicini. Specifičnosti veterinarske nuklearne medicine se odnose na životinje kao pacijente, nedostatak svjesne saradnje životinja, sigurnosne mjere zaštite od zračenja u svjetlu slobodnog kretanja životinja, manjak obučenog osoblja te zainteresiranost veterinara za nuklearne pretrage. Međutim, najveći problem je financijske prirode i on izravno utječe na dostupnost veterinarskih nuklearnih usluga. Razvijene zemlje prednjače u dostupnosti veterinarskih nuklearnih usluga.

Veterinarska nuklearna snimanja se mogu izvoditi predklinički u istraživačke svrhe i klinički u dijagnostičke svrhe. Izotopi koji emitiraju visoke energije se mogu koristiti u terapijske svrhe u svrhu liječenja. Upotreba različitih izotopa u dijagnostičke i terapijske svrhe kod istog oboljenja je omogućila nastanak novog medicinskog polja pod nazivom teranostika. Nuklearne slike nastaju tako što se radioaktivni izotopi nakon intravenske aplikacije akumuliraju u organima životinja opisujući njihovu morfologiju i funkciju. Snimanje se vrši na scintilacijskoj gama kameri. Nuklearne snimke se zove nuklearni skenovi, a tehnika snimanja scintigrafija. Radioaktivni izotop koji se najčešće koristi za dijagnostička snimanja je radioaktivni tehnecij Tc-99m, dok se u terapijske svrhe najčešće koristi radioaktivni jod I-131. Od scintigrafija se kod životinja najčešće izvode scintigrafije štitnjače, kostiju, jetre i bubrega, s tim da za svaku pretragu postoji posebna klinička indikacija.

U svijetu se povećava broj kako proizvodnih životinja tako i kućnih ljubimaca, a shodno tome i potreba za veterinarskim uslugama koje je potreno stalno unaprijeđivati. Iz tog razloga će rasti potreba za novim dijagnostičkim i terapijskim procedurama, uključujući i nuklearne.

Novi trendovi u veterinarskoj nuklearnoj medicini koji se veoma brzo razvijaju slijede trendove u humanoj medicini i uključuju i istraživanja i kliničku veterinarsku medicinu.

Ključne riječi: Izotopi, scintigrafija, snimanje, veterinarska nuklearna medicina