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DIAGNOSTIC IMAGING TECHNIQUES IN VETERINARY PRACTICE: A REVIEW

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Abstract

Today the practice of most medical disciplines is almost unrecognizable without modern radiology since the outcome of any treatment largely depends upon how appropriately the particular medical condition has been diagnosed. Imaging technology is fascinating, is developing rapidly, and is without doubt beneficial in medical and veterinary practices. Over the last decade, the quality of diagnostic imaging equipment and the habit of using it for diagnosis in veterinary practice has greatly improved. There are number of imaging techniques like ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine and scintegraphy that are currently available for clinical diagnosis leading to greater demands and expectations from veterinary clients. The modern imaging diagnosis though well established in medical science is still in its infancy in veterinary practice due to heavy initial investment and maintenance costs, lack of expert interpretation, requirement of specialized technical staff and need of adjustable machines to accommodate the different range of animal sizes. The present review briefly gives an update of the development and present status of imaging techniques in veterinary medical diagnosis.

Keywords: Computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine and scintegraphy, ultrasonography.

1. Introduction

Medical diagnostic technology has made rapid strides after the advent of computer. Imaging techniques in medical practice have contributed significantly to the progress of health care since the discovery of x–rays in 1895 [1, 2]. For a considerable number of years after Roentgen first described the use of ionizing radiation at that time called 'X-rays' in 1895, this remained the only method for visualizing the interior of the body. Imaging techniques help to establish a standard database of normal anatomical, physiological and functional parameters that could be used for clinical and research purpose [3]. Many of the advances in human diagnostic medicines are translated into veterinary medicine in the developed countries. In brief, newer branches like Imaging, Radiodiagnosis, Telemedicine, Telesonography and Teleradiology have emerged. All these imaging modalities have brought sea change in the diagnosis of a clinical case. Precise and an instant diagnosis of an intricate case can be made with their usage Broadly, the instrumentation /devices devised with the modern technology in the present digital age are, digital radiography, Ultrasonography (USG), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Bone Scintigraphy, Digital Substraction Angiography (DSA), Laparoscopy Thoracoscope, Theloresectoscope, Rhinoscope, Otoscope, Endoscopy [4]. These x–ray diagnostic techniques differ from each other based on the mode of image acquisition and its storage, installation cost and safety system.

1.1 Digital radiography

Digital radiography (DR) systems work differently from CR systems. Rather than using a traditional X-ray cassette, a fixed panel underneath the X-ray table is exposed instead. DR units are then further divided into *indirect conversion* and *direct-conversion* systems (AGFA). In indirect-conversion, the panel (comprised of scintillated material) converts X-ray energy to light. It is subsequently transformed to a digital signal and then converted to a radiographic image [5]. Direct-conversion systems have a photoconductor layer capable of converting X-rays directly into a digital signal rather than into light first. In both systems, the resultant radiographic image appears on a computer screen within seconds [6]. The physical principals of digital radiography (DR) do not differ from conventional projection radiography (screen–film radiography). In DR all the conventional X–ray equipments like X–ray machine, table, grid, etc., are same. However, conventional radiography has film which serves both detector as well as storage device while in DR image is generated by digital detectors which is then is stored in digital medium [7]. In general, digital radiography is divided into computed radiography (CR) which bears an image plate (IP), IP reader, an analog to digital converter (ADC), and a computer that process the image [8, 9] and direct digital radiography (DDR) which readout the image directly barring any intermediate processing step (reader) and thus, possesses an integrated readout property [10, 11, 12, 13]. One more digital imaging system *i.e*., charged coupled devices (CCD) are available which are considered with DDR hardware as image is directly sent to a computer. The main difference that exists between CR and DDR involves image acquisition and not the final result [7]. Initial purchasing costs of digital radiography systems are relatively high; however, this may be outweighed by the ongoing costs of buying film, wet-processing chemical purchase/disposal, increased patient anaesthesia/sedation time, frequent radiographic re-takes and volume of storage required when keeping film radiographs [14].

1.2 Ultrasound

Sonography has become an essential imaging modality in the field of veterinary medicine and is increasing in popularity since it has smaller size, high level of autonomy, high image quality and accessible prices. The development and improvement in different diagnostic imaging modalities particularly ultrasound, computed tomography, magnetic resonance imaging leading to earlier and more accurate diagnoses of disease using noninvasive techniques [15]. Ultrasound is a versatile imaging technique that can reveal the internal structure of organs, often with astounding clarity. This imaging technique is unique in its ability to image patient anatomy and physiology in real time, providing an important, rapid and noninvasive means of evaluation. Applications of ultrasound in ruminants have not been fully exploited, except in pregnancy. In small animal and equine practice, ultrasound is routinely used as a diagnostic aid. The most versatile transducer configuration for small animal imaging is the sector scan because the narrow part of the image is at the skin surface and the viewed area gets wider with increasing depth in the patient [16]. Recent advances in ultrasound technology in both hardware and software have resulted in the production of superior images and the widespread use of ultrasound. Ultrasonography provides information about size, shape, and location of structures; moreover, it also provides information about the softtissue architecture of the structure or organ being examined [17]. Ultrasonography is best for distinguishing solid from cavities (fluid-filled) structures and provides internal detail not demonstrated radiographically. Thrawat et al. [18] used trasnabdominal examination of ultrasound for the diagnosis of johns diseased in goats, according to them this imaging modality is a unique method for non-invasive evaluation of the location, diameter, motility, wall and intraluminal contents of various parts of the intestine. Zongo et al. [19] employed the use of ultrasound to assess postpartum uterine involution and ovarian activity. Kurt and Cihan [20] evaluated 100 cattle ultrasonographically in order to identify their abdominal disorders. Ultrasound has a great role on the formulating clear diagnosis on gastrointestinal disorders in dogs. The whole thickness of stomach or intestinal wall can be visualized and measured, as well as adjacent structures such as lymph nodes. Also can be assessed the gastric and intestinal motility, observing the peristaltic movements in real time [21]. Although ultrasonography is not as useful for broad examination of the axial, appendicular skeleton or the skull as are survey radiographs, some information may be obtained from ultrasonographic evaluation of muscles, tendons, and the joints, as well as examination of the orbit and brain (in animals with open fontanels) [22].

Ultrasonography seems to have a promising future in veterinary medicine, particularly for the assessment of intra-periabdominal disease. Ultrasonography is viewed as the single most versatile addition to the noninvasive and nonsurgical armamentarium of the veterinary clinician since the advent of fibreoptic endoscope. Although other sophisticated imaging modalities like CT and nuclear imaging can provide additional information, the accessibility and cost effectiveness of these procedures do not make these as promising as ultrasonography. Ultrasonography in contrast to conventional x–rays examinations distinguishes well between soft tissues and is preferred for soft tissue examinations like abdomen including the obstetrical applications. In relation to skeletal tissue (bone) and pulmonary tissue, ultrasonography is least preferred as the sound waves cannot pass through the air/gas and the bony tissue. This also restricts the application of ultrasound in the brain examination except in young ones where fontanels are still open [23].

1.3 Computed tomography

The first CT scanner capable of imaging the whole body CT scanner was first was developed by Robert Ledley and installed in 1973 at Minnesota University [24]. According to Ohlerth and Scharf [25], since being introduced to veterinary medicine in the 1970s, CT has become one of the most important imaging modalities used in the diagnosis of neurological, oncological and orthopaedic conditions in small animals (canines and felines). CT has been an extremely significant development which has a unique cross sectional imaging ability useful for the diagnosis of tumors, malformations, inflammation, degenerative and vascular diseases and trauma. It is also very helpful in cases of acute trauma involving complex areas of anatomy such as the skull, spine and pelvis. Spiral tomography, an improved tomographic technique, allows continuous rotation wherein an object is slowly and smoothly slid through the X–ray ring to be imaged. Subsequent improvisation of helical CT lead to development of multi–slice CT wherein multiple rows of detectors are used to capture multiple cross–sections simultaneously instead of single detectors [26, 27]. In contemporary third or fourth generation scanners only a single slice at a time is acquired [28]. Currently, another type of CT scanner (Cone beam CT) has been introduced for veterinary diagnostics that possesses image plate rather than detectors thus, cost effective. The image quality and resolution, being at par with the contemporary machines, but it has significantly slower image acquisition rate [29]. Like conventional radiography, CT uses ionising radiation to form an image of a patient. However, where the former produces a two-dimensional (2D) image of the portion of the patient's body included in the collimation, CT gives us several transverse images as cross-sectional slices through the animal [30].

CT may be indicated in patients where previous conventional imaging methods such as ultrasound and radiography have failed to provide enough information or a conclusive diagnosis. This advanced imaging modality is particularly useful in the diagnosis and staging of most tumours [30], and is considered to be particularly sensitive for identifying skeletal changes [31]. This makes CT invaluable for assessing many orthopedic conditions where conventional radiography does not provide enough information. Due to the improved contrast resolution, soft tissue is also visualized relatively well when compared to a radiograph. Contrast media are often used during CT studies to highlight suspicious lesions and assist with disease diagnosis, by increasing vascular and soft tissue contrast [32].

1.4 Magnetic resonance imaging

The first use of nuclear magnetic resonance as a 2D imaging technique was developed by Paul Lauterbur, a chemist at the State University of New York, in 1972 [33]. Paul Lauterbur (University of Illinois) and Sir Peter Mansfield (University of Nottingham) were awarded the 2003 Nobel Prize in Physiology or Medicine, reflecting the importance of MRI in Medicine [34]. The technique is widely used in medical hospitals and small animal practice for diagnosis of numerous diseases, staging of the diseases and for follow–up without the risk of exposure to ionizing radiation. MRI is an increasingly popular diagnostic tool, now widely available across the veterinary industry. However, in veterinary medicine MRI is still in its infancy and its use is infrequent. To date, MRI has been used in developed countries in clinical cases as well as a research tool especially for CNS diseases in small animals [35]. MRI is a highly sensitive and noninvasive technique providing accurate and detailed anatomic images with good contrast and spatial resolution which is used to investigate the anatomical and physiological function of the body tissues. Due to its superior soft-tissue contrast, MRI remains the primary method of imaging for diagnosing soft-tissue damage such as meniscal, ligament and tendon tears (as well as occult bone injuries), according to Crues and Bydder [36]. Labruyère and Schwarz [32] suggest that MRI is superior for diagnosing pathology of the central nervous system, while CT remains the gold-standard imaging modality for scans of the thorax. The positive contrast medium gadolinium (Gd) is often used to identify the location and character of CNS lesions [37]. CT also gives superior osseous detail compared with MRI, which makes it a better imaging tool to use for orthopedic conditions. MRI has a wide spectrum of application. It can be used for imaging all body regions in small animals, but only the extremities and the head can be imagined in large animals. It is useful in answering many questions related to the musculoskeletal diseases in animals such as understanding the pathogenesis of navicular disease, traumatic arthritis and osteochondrosis in equines and wobbler syndrome in dogs. The newer applications of MRI are Magnetic resonance angiography and MR spectroscopy. It is especially used to differentiate an inflammatory process from a neoplastic mass, tumors from peritumoral oedema. It is more specific and sensitive in detecting localizing and differentiating osteomyelitis, cellulites and abscess. However, its use is contraindicated in pregnancy [35].

1.5 Nuclear scintigraphy

Nuclear medicine scintigraphy is a diagnostic technique that requires gamma emission radioisotope (radiopharmaceutical agent). Henri Becquerel radioactivity discovery two months later too was a serendipitous [38], but it was Georg de Hevesy who applied the radioisotopes to the study of plant and animal metabolism, which later earned him Nobel Prize in 1943 [34]. Nuclear scintigraphy is a highly sensitive advanced procedure in which radioisotopes are used to detect the functional abnormalities of the body system. Scintigraphy is a less known diagnostic imaging technique. Although it is similar to competitive methods such as radiography, ultrasound, endoscopy, there is one basic difference. By all the other methods only morphological objects can be visualized whereas scintigraphy has the advantage of the so-called physiological imaging. This means, that scintigraphy is able to visualize and quantitate the distribution of different materials in the living organism indicating the normal (physiological) or abnormal (diseased) processes of the object. That can be the basis of a sensitive, specific and non-invasive diagnostic method supporting the clinician's diagnosis. As a part of combined modality imaging systems, scintigraphy gives useful data for the medical and veterinary clinicians as well. Skeletal scintigraphy is the most commonly performed scintigraphy (or bone scanning) procedure in veterinary practice. It offers high sensitivity for detecting early disease, and the ease of evaluation of the entire skeleton (or a region) makes it an ideal tool for screening cases of obscure or occult lameness. However, Scintigraphy can be used to look at a variety of organ functions including brain, heart, lung, kidney, liver, thyroid etc [39, 40, 41]. It is also very useful in the diagnosis of occult lameness, lung perfusion and ventilation and patency of the ureter in both large and small animals. Also used for vertebral column imaging and monitoring the progress of fracture healing and in tumor detectionVeterinary Nuclear Medicine procedures can be subdivided into two main categories: isotope diagnostics (called also scintigraphy) and radiation (isotope) therapy [42], similar to the situation in human medicine. The major limitation with nuclear imaging is of the large dosage of radionuclide [34]. Apart from dose to the patient, it may not detect the early stages of metastatic disease and myeloma [43]. Low spatial resolution and commonly encountered false positives due to degenerative disease or trauma are other few limitations. Thus, whole body imaging in nuclear medicine often remains confined to specific organ imaging or of tumors [34].

1.6 Laparoscopy

Laparoscopy has been a valuable diagnostic and therapeutic tool in human clinical medicine. Limited abdominal exploration (keyhole) for laparoscope guided organ examination permits precise and accurate site localization of the various internal organs [44, 45] and excision biopsy is indicated to ascertain a correct diagnosis, specific therapy and accurate prognosis [46]. Laparoscopy is a minimally invasive diagnostic modality which aids in a best way to document mucosal inflammation- hyperemia, active bleeding, irregular mucosal surface, and facilitates biopsy in tubular organs like the GI tract, and repiratory and the urogenital organ systems by means of a telescope through a small incision made in the abdominal wall. It is an endoscopic procedure that bridges the gap between clinical evaluation and surgical exploration. Direct visualization of the organ with a token invasive method also helps the clinicians to imply an assiduous control over the technique without invasive exploratory surgery and proves its superiority over other non invasive diagnostic techniques like X ray, ultrasound, MRI. Moreover, laparoscopy requires minor surgical intervention; it provides one of the only available practical means of making repeated direct examination of abdominal viscera [47]. Only in the last 15 years, its use has been extensive in various animal species for research and clinical diagnostic and therapeutic purposes. Laparoscopic surgery offers significant advantages over open surgeries in fields of cholecystotomy, appendicectomy, vagotomy, hernia repair and adhesion release etc. For gynaecological problems like ovarian cyst or in the case of oophorectomies and hysterectomies, laparoscopic surgery (scarless surgery) is now considered a better alternative in addition to laparoscopic sterilization. The most advantageous characteristic of laparoscopy is that it allows direct examination of abdominal cavity with only minimal and superficial surgical intervention. Thoracoscopy has been employed in man for the diagnosis and treatment of diseases of the pleura, lung, mediastinum, great vessels, pericardium and oesophagus. Visceral inspection of the thoracic cavity by thoracoscopy has been used to provide a more accurate diagnosis and prognosis in horses affected with pleuropneumonia and other thoracic and oesophageal disorders. Thoracoscopy allows visualization and biopsy of a large surface of the lung and provides adequate specimen for histopathological diagnosis [35].

1.7 Fluoroscopy

Fluoroscopy is a lesser-known diagnostic imaging tool, using ionising radiation to obtain a real-time moving image of a patient. Real-time is generally considered to be 30 frames per second which, according to Boone, Bushberg, Leidholdt, and Seibert [48], is sufficient to give the appearance of continuous motion. Digital fluoroscopic systems also record a sequence of images, which can be viewed as a movie loop and saved to a picture archiving and communications system for later retrieval [48]. Easton [30] describes the multiple stages of image formation with fluoroscopy: a basic X-ray tube is attached to an image intensifier, which allows the X-ray photons that pass through the patient to be turned into light when they emerge from the other side. The intensity of this light is then multiplied and transformed into photoelectrons, via the use of a photocathode. In the final stage, the photoelectrons strike the output phosphor and anode components of the machine, after which an image appears on a television screen. Applications for using fluoroscopy are relatively few when compared to the other imaging modalities found in general practice.

2. Challenges in use of imaging techniques in veterinary practice

Veterinary radiology is a long established subject discipline in veterinary science. Despite or perhaps because of this long ancestry, it is worthwhile examining the extent of the subject's boundaries and its place in veterinary medicine. One can ask what imaging modalities fall under the remit of the subject and why they do so. Veterinary activities have always been concerned with the diagnosis and treatment of disease, with clinical and experimental animal research, and with agriculture, to select but a few areas of interest. The limits of what radiologists can and cannot do becomes unclear as the breakdown of traditional barriers between disciplines, considered essential to progress in medical education and scientific progress, continues [49]. It has always been the case that the collection and use of image-related data are not the sole preserve of veterinary radiologists; uncertainties can exist as to who should be involved. The radiology community, both users and suppliers alike, has to ask what value imaging brings to collaborative work and how this value is best realized [50].

Veterinary imaging has the privilege and challenges that go with continued development of current and new imaging technologies and modalities. Despite the range of imaging technologies, most of them are based on either sound or electromagnetic waves or a combination thereof. Optical imaging is an emerging modality that promises information on morphology, physiology, and tissue composition [51]. Training and retaining these individuals in veterinary imaging is not trivial; the challenge in doing so, and the consequences of failure are well recognized [52]. So, up to date and active specialists are needed. There is a limited basis due to a general lack of practicing knowledge of those imaging modalities and, particularly for CT, the relatively high cost of the tests.

Not every animal owner is willing or able to spend several hundred dollars on a sonogram or several thousand on a CT. Many general veterinary practitioners do not train in the field of sonography specifically. Rather than investing the time in learning and mastering sonography, they will either get by without it or contract to outside specialty imaging agencies or mobile practices. These practice raises the questions of which can, and who should, perform animal sonograms [53].

There are currently no veterinary sonography accreditation bodies or certifications (outside of possessing a doctor of veterinary medicine degree), and no dedicated programs are currently being offered. There are some short-term training courses available for a substantial fee which does offer hands-on training, but the majority of veterinary sonographers learn the science and application through on the job training, just as diagnostic medical sonographers did so many years ago. The field of veterinary sonography is just as operator dependent as in human medicine. Similarly, there are many different types of protocols currently being utilized. Unlike in human medicine, there are no established guidelines or standards of practice on what a specific examination must include for consideration for reimbursement [53].

Fluoroscopes are also generally confined to referral hospitals and academic institutions due to cost and the specialised level of diagnostic imaging knowledge needed in order to interpret the images generated accurately. Practices using fluoroscopy must adhere to the local rules as set out by their Radiation Protection Advisor (RPA) and work within the guidance given in the IRR99 documents. Patients undergoing examination with most of imaging techniques will usually require general anaesthesia or deep sedation in order to ensure complete immobilization [53].

3. Health and safety

Strict health and safety protocols must be adhered to when working with ionizing radiation. An external Radiation Protection Advisor (RPA) must be appointed to devise local rules, systems of work and written arrangements for working with X-rays in practice safely. Documents and protocols will be tailor-made for each practice and overseen on a daily basis by the Radiation Protection Supervisor(s) who work on the premises. The Ionising Radiations Regulations; Guidance Notes for the Safe Use of Ionising Radiations in Veterinary Practice should be available according to the countries used the imaging equipments which is important when working with X-rays in veterinary practice. Personal protective equipment, such as aprons, thyroid guards and gloves of a suitable thickness of lead-equivalent material (as directed in the local rules) must be available for use where necessary.

Personnel should take particular care when entering MRI scanning rooms, as the machines are effectively very large magnets. Ferromagnetic objects such as oxygen cylinders, scissors, stethoscopes, hair grips, coins, keys and mobile tables will be drawn towards the magnet when they get too close, and this could result in serious injury or even death of personnel if hit or trapped by these objects. It is vital that all workers and visitors are aware of this risk and take steps to avoid them. MRI scanners can be differentiated by their magnetic strength into low-field and high-field scanners, the latter posing a higher potential health and safety risk due to the higher field strength. The functionality of medical devices such as pacemakers may be disrupted by the strong electromagnetic fields of an MRI scanner. For this reason, staff must read and sign a health and safety questionnaire prior to working with MRI, to ensure they are deemed safe to do so. Further contraindications to working in MRI are ferromagnetic implants (for example, orthopaedic plates) and foreign bodies, which have the potential to heat up and/or migrate through tissues (54).

Unlike conventional X-ray machines, instead of a single tube head mounted above the patient, the high-powered tube located inside a CT machine rotates around the patient's anatomy, slice by slice. As the X-ray beam is attenuated by the patient (weakened, depending upon the density of the tissue through which it travels), a panel of detectors on the opposing side receive the remaining radiation, producing an electrical signal. Labruyère and Schwarz [32] describe how the signal generated is directly proportional to the density of the tissue it has penetrated.

4. **Conclusion**

There are several options available to the veterinary clinician to perform diagnostic imaging studies. The choice will depend on a number of factors, including cost, availability, expertise of staff to carry out the examination and interpret the images afterwards and the disease process under investigation. Often there is no right or wrong imaging modality for a case, and using more than one method to build a complete picture of the condition may be of great benefit. The various challenges facing the veterinary imaging community are more exciting than problematic. The problems like high cost of the equipments, few trained professionals and safety issues can be assemble and coordinate as many skilled minds, from as many spheres of activity as possible, to focus on advancing the field.

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