Artificial intelligence in veterinary diagnostics

Artificial intelligence is becoming increasingly important in veterinary medicine and is likely to play a significant role in how the profession develops in the future. It is already impacting the way veterinarians practice, with several technologies readily available. Its application to the interpretation of diagnostic images, clinicopathological data and histopathology has been demonstrated. It is hoped that these technologies will increase the speed and accuracy of a diagnosis. This article reviews some studies investigating the application of artificial intelligence to the diagnosis of disease in animals and considers future uses and limitations of the technology.

Harriet Ash Oliver Broome BSc BVMedSci BVM BVS MRCVS, Resident in Small Animal Internal Medicine; University of Liverpool, Small Animal Teaching Hospital, Chester High Road, CH64 7TE. Email: hbroome@liverpool.ac.uk

Key words: Artificial intelligence | Diagnostics | Technology | Veterinary

Submitted: 4 April 2024; accepted for publication following double-blind peer review: 29 April 2024

Artificial intelligence has become commonplace, helping users select the next song on a playlist or the next word in a message. As it continues to develop, its use will also become routine in veterinary practice. As with any new technology developed within the profession, it is important to understand its application and how it works.

Many areas of veterinary medicine will benefit from the development of artificial intelligence, with research already showing how it can be applied for disease surveillance (Bollig et al, 2020) and predicting disease development within a population (Biourge et al, 2020). One of the areas where its use has already been demonstrated is in the diagnosis of disease. Technology that helps to make faster diagnoses with greater confidence will expedite how veterinary medicine is practised, allowing more time for other vital tasks.

Artificial intelligence is the development of technology that allows computer systems to perform tasks that would previously have required human intelligence. There are several different types of artificial intelligence. The subset that has been most investigated in veterinary medicine is machine learning, which is where sample data is used to train a system to recognise patterns and learn without explicit instructions (Cui et al, 2020), for example, a social media platform correctly grouping photographs of the same person. Deep learning is a subset of machine learning, and these models are made up of neuronal networks. Neuronal networks are based on neurons in the human brain and act to receive and process information before giving an output (Cui et al, 2020).

Diagnostic imaging

One of the applications of artificial intelligence in veterinary medicine that has been most studied is diagnostic image analysis (Hennessey et al, 2022). This is because large amounts of digital data are required in the development of certain types of artificial intelligence and imaging modalities, like radiography, produce digitalised data that can be verified. For example, the more images that are provided to train an artificial intelligence model to differentiate between a thoracic and abdominal radiograph, the more likely it will be able to recognise and sort future images correctly.

One of the initial studies conducted designed an artificial intelligence model using radiographs with and without a coxofemoral joint (McEvoy and Amigo, 2013). The model was then able to distinguish between radiographs that had hips and those that did not and served as the initial proof of concept of the application of artificial intelligence to veterinary medicine. This work was expanded to create a model that could classify hip dysplasia based on the Fédération Cynologique Internationale scoring system, which scores from A–E, with the system performing best with hips that were at either end of the grading system (McEvoy et al, 2021).

While the initial studies investigating artificial intelligence were in musculoskeletal disorders, its use has also been applied to other conditions. For example, studies have used artificial intelligence to identify cardiomegaly in a radiograph (Burti et al, 2020; Boissady et al, 2021). One study showed high agreement between vertebral heart scores calculated by board-certified specialists and artificial intelligence (Burti et al, 2020). Using artificial intelligence to identify abnormalities in the pulmonary parenchyma has also been investigated. One study developed a model for identifying pleural effusion. The software correctly identified pleural effusion in 37 out of 41 radiographs that had a confirmed pleural effusion and correctly classified 18 out of 21 of the normal cases (Müller et al, 2022). A separate model was able to identify cardiogenic pulmonary oedema correctly in 42 of 46 cases, giving the model an accuracy, sensitivity and specificity of 92.3%, 91.3% and 92.4%, respectively (Kim et al, 2022). It is also possible to train models to identify more than one abnormality; for example, artificial intelligence capable of identifying 15 different thoracic lesions including pulmonary masses, pneumothorax and alveolar patterns has been developed (Boissady et al, 2020).

Artificial intelligence has been applied to abdominal ultrasound and has been used to try and distinguish between inflammatory bowel disease and small cell lymphoma in cats, a typically challenging differentiation. In one study, ultrasound images were combined with complete blood cell count and biochemistry data to try and identify which cats had alimentary lymphoma and which had inflammatory bowel disease. Interestingly, they found that merging clinicopathological data with the ultrasound results did not substantially improve the model's accuracy (Basran et al, 2023). When applied to echocardiography, an artificial intelligence network was trained to measure left ventricular dimensions, and its performance was indistinguishable from that of specialists (Stowell et al, 2024).

A number of studies have also investigated its application to advanced imaging (Banzanto et al, 2018; Spiteri et al, 2019). It has been used to classify intracranial neoplasia; Banzanto et al (2018) used artificial intelligence to distinguish between intracranial meningiomas and gliomas on magnetic resonance imaging, using histopathology results to develop the model. Additionally, artificial intelligence was used to investigate the connection between magnetic resonance imaging features of Chiari-like malformation and clinical signs including pain, suggesting that this technique may assist with diagnosis in the future (Spiteri et al, 2019).

The application of artificial intelligence to the interpretation of diagnostic imaging could provide a quick way to verify a radiograph, which may be particularly useful in emergencies where additional support with reaching a diagnosis is required. Furthermore, the use of technology that can help support the diagnostic process may help to reduce the rate of error. Error in the interpretation of radiographs occurs in both human and veterinary medicine (Alexander, 2010). A study comparing radiological interpretation with post-mortem findings at one institution found a radiologic error rate of 4.6% (Cohen et al, 2023), which is comparable to that found in human medicine (Siegle et al, 1998). Artificial intelligence can also be used to identify more subtle changes than can be identified by the human eye. One study showed that an artificial intelligence tool called Mia could detect more subtle changes in mammograms than radiologists and could increase the rate of detection of breast cancer by 13% in humans (Ng et al, 2023).

Artificial intelligence radiograph interpretation is already available in practice.

Clinical pathology

There are clear advantages of the application of artificial intelligence to clinical pathology, with the fast interpretation of cytology and blood results aiding diagnosis (Basran and Appleby, 2022). Furthermore, this is one of the areas where veterinarians are already seeing an impact impractice, with the availability of in-house machines that interpret basic cytology (Nagamori et al, 2021; Vasilatis et al, 2021).

The application of artificial intelligence to the cytological interpretation of blood smears has been demonstrated. In chickens, the malaria parasite (*Plasmodium gallinaceum*) was successfully detected on blood smears (Kittichai et al, 2021). The detection of intracellular organisms would also apply to companion animals, especially as the importation of animals and climate change bring more diseases identifiable on blood film analysis, eg ehrlichiosis (Beugnet and Chalvet-Monfray, 2013; Norman et al, 2020). It was also demonstrated that artificial intelligence could use haematology changes to identify which samples were more likely to contain *Babesia canis* (Pijnacker et al, 2022). This may be useful to help identify which animals should have further investigations for this disease. One study created a machine learning model that could diagnose hypoadrenocorticism using serum biochemistry and complete blood cell count results with a sensitivity of 96.3% and a specificity of 97.2% (Reagan et al, 2020).

Some systems that aid with diagnosis are already available in practice. One such system that has been developed is the VETSCAN IMAGYST, which is able to identify parasite oocytes in faeces and showed similar results to the conventional centrifugal flotation method, potentially aiding in diagnosis (Nagamori et al, 2021). The Idexx SediVue Dx is already used in many practices and analyses urine sediment, with studies showing a moderate agreement with manual analysis for detecting casts in the urine of cats (Vasilatis et al, 2021).

Histology

Interpretation of histopathology is typically undertaken by specialists and is an important diagnostic step in cases with tissue samples. Technology that allows the digitisation of whole slides has been available since 1999, and it permits the development of artificial intelligence to aid the interpretation of histopathology (Zuraw and Aeffner, 2022).

One model was designed to differentiate the seven most common types of skin tumours in dogs: trichoblastoma, squamous cell carcinoma, peripheral nerve sheath tumour, melanoma, histiocytoma, mast cell tumour and plasmacytoma. It was able to identify a tumour from histopathology with a 95% accuracy, compared with 98%

accuracy of trained pathologists (Fragoso-Garcia et al, 2023). Mitotic count is an important element of grading canine tumours. One study demonstrated that computerised image analysis could identify high variation in the mitotic count in different areas of the tumour. Different areas of a tumour having different mitotic counts could lead to intra-observer variations and has the potential to alter the treatment plan and prognosis for the patient (Bertram et al, 2020).

Future uses

Artificial intelligence will not only impact how diagnoses are made but will also affect other areas of the profession. It is likely to be used in veterinary education, where it may help provide a more individualised experience by adapting to a specific student's pace and needs (Sun et al, 2023). It could be used to create artificial client scenarios, allowing students to practice their communication skills with interactive conversations and feedback (Sun et al, 2023).

Artificial intelligence will likely help with practice workflow. For example, it may prove useful in inputting clinical information into patient records (Basran and Appleby, 2022). It may also aid with scheduling appointments and creating staff rotas.

It is likely to continue to play a role in veterinary research and has already proved invaluable in medical research. For example, artificial intelligence was instrumental in developing the SARS-CoV-2 vaccine, where machine learning was used to identify potential drug targets (Sharma et al, 2022). In veterinary medicine, there is increasing research into areas like proteomics, metabolomics and genomics. These types of investigations generate large amounts of data, and artificial intelligence may provide a way to analyse and interpret these data, with the aim of offering more individualised treatment for patients (Akinsulie et al, 2024).

One area of artificial intelligence which is rapidly developing is generative artificial intelligence. This type of artificial intelligence, eg ChatGPT, is capable of generating data like texts and images (Raza et al, 2024). This form of artificial intelligence is likely already being used by clients to try to diagnose their pets by entering symptoms into the program, and it may well have an application in the future of veterinary diagnostics (Abani et al, 2023). In humans, GPT-4 was used to triage patients presenting to an emergency department and had excellent agreement with the triage team and gold-standard care (Paslı et al, 2024).

Challenges and limitations

Artificial intelligence used in diagnosis in veterinary medicine will still require the expertise and scrutiny of a veterinary surgeon to enable the correct interpretation of the results with an understanding of the limitations of that test. As this technology develops, some limitations and challenges need to be considered.

Data are crucial for the development of artificial intelligence, so ownership and management of these data will become instrumental in the advancement of this technology in the profession (Appleby and Basran, 2022). Medical records are likely to be vital in the development of certain types of artificial intelligence. Veterinarians are required to protect the privacy of their clients, so informed consent for the use of medical records will be expected.

Bias is a common limitation of artificial intelligence technologies. Bias can occur if training data sets are skewed, for example by breed or geographic distribution (Bellamy, 2023). One of the challenges of artificial intelligence in veterinary medicine is breed variation. If a model is built with data from predominately brachycephalic dogs, it may not apply to Labradors. Different geographic populations are also likely to lead to different data because of variations in disease prevalence; for example, a model developed in the UK is unlikely to include many dogs with *Leishmania*, so it may not apply to populations where the disease is prevalent. Bias can also be introduced by the quality of the data; for example, high-quality radiographs vs poor-quality ones (Appleby and Basran, 2022). Additionally, these models need to be verified by veterinarians to ensure that the training data are accurate, and there is likely to be a degree of variation in opinions. All these different factors can contribute to how accurate a system is and how likely it is to provide the correct diagnosis.

Veterinary artificial intelligence will need to be regulated to ensure that the quality of the resources is appropriate for clinical practice. Currently, there are no regulations in place, so this will need to be developed as the technology progresses, and veterinarians must be involved with this process (Bellamy, 2023).

Conclusions

Artificial intelligence is likely to become commonplace in veterinary medicine and is already playing a role in the interpretation of some cytology. In the future, it is probable that artificial technology will play a significant role in diagnosing disease in animals, particularly in areas like diagnostic imaging. As the technology develops it will be important for veterinarians to understand the applica-

KEY POINTS

- Artificial intelligence is likely to play a significant role in diagnosing disease in veterinary patients in the future.
- The application of artificial intelligence has already been demonstrated in several areas of veterinary diagnostics including image analysis, histopathology and clinical pathology.
- Artificial intelligence will also be important in other areas of veterinary medicine like disease surveillance, education, logistics and in the research and development of novel treatments.
- There are several limitations to artificial intelligence that should be considered, especially when interpreting results generated by the technology.

tions and limitations. It will also be important to have veterinarians involved in the development and regulation of new technologies.

References

Abani S, De Decker S, Tipold A, Nessler JN, Volk HA. Can ChatGPT diagnose my collapsing dog? Front Vet Sci. 2023;10:1245168. https://doi.org/10.3389/fvets.2023.1245168

Akinsulie OC, Idris I, Aliyu VA et al. The potential application of artificial intelligence in veterinary clinical practice and biomedical research. Front Vet Sci. 2024;11:1347550. https://doi.org/10.3389/fvets.2024.1347550

Alexander K. Reducing error in radiographic interpretation. Can Vet J. 2010;51(5):533–536

Appleby RB, Basran PS. Artificial intelligence in veterinary medicine. J Am Vet Med Assoc. 2022;260(8):819–824. https://doi.org/10.2460/javma.22.03.0093

Banzato T, Bernardini M, Cherubini GB, Zotti A. A methodological approach for deep learning to distinguish between meningiomas and gliomas on canine MR-images. BMC Vet Res. 2018;14(1):317. https://doi.org/10.1186/s12917-018-1638-2

Basran PS, Appleby RB. The unmet potential of artificial intelligence in veterinary medicine. Am J Vet Res. 2022;83(5):385–392. https://doi.org/10.2460/ajvr.22.03.0038

Basran PS, Shcherban N, Forman M et al. Combining ultrasound radiomics, complete blood count, and serum biochemical biomarkers for diagnosing intestinal disorders in cats using machine learning. Vet Radiol Ultrasound. 2023;64(5):890–903. https://doi.org/10.1111/vru.13250

Bellamy JEC. Artificial intelligence in veterinary medicine requires regulation. Can Vet J. 2023;64(10):968–970

Bertram CA, Aubreville M, Gurtner C et al. Computerized calculation of mitotic count distribution in canine cutaneous mast cell tumor sections: mitotic count is area dependent. Vet Pathol. 2020;57(2):214–226. https://doi.org/10.1177/0300985819890686

Beugnet F, Chalvet-Monfray K. Impact of climate change in the epidemiology of vector-borne diseases in domestic carnivores. Comp Immunol Microbiol Infect Dis. 2013;36(6):559–566. https://doi.org/10.1016/j.cimid.2013.07.003

Biourge V, Delmotte S, Feugier A, Bradley R, McAllister M, Elliott J. An artificial neural network-based model to predict chronic kidney disease in aged cats. J Vet Intern Med. 2020;34(5):1920–1931. https://doi.org/10.1111/jvim.15892

Boissady E, de La Comble A, Zhu X, Hespel AM. Artificial intelligence evaluating primary thoracic lesions has an overall lower error rate compared to veterinarians or veterinarians in conjunction with the artificial intelligence. Vet Radiol Ultrasound. 2020;61(6):619–627. https://doi.org/10.1111/vru.12912

Boissady E, De La Comble A, Zhu X, Abbott J, Adrien-Maxence H. Comparison of a deep learning algorithm vs. humans for vertebral heart scale measurements in cats and dogs shows a high degree of agreement among readers. Front Vet Sci. 2021;8:764570. https://doi.org/10.3389/fvets.2021.764570

Bollig N, Clarke L, Elsmo E, Craven M. Machine learning for syndromic surveillance using veterinary necropsy reports. PLoS One. 2020;15(2):e0228105. https://doi.org/10.1371/journal.pone.0228105

Burti S, Longhin Osti V, Zotti A, Banzato T. Use of deep learning to detect cardiomegaly on thoracic radiographs in dogs. Vet J. 2020;262:105505. https://doi.org/10.1016/j.tvjl.2020.105505

Cohen J, Fischetti AJ, Daverio H. Veterinary radiologic error rate as determined by necropsy. Vet Radiol Ultrasound. 2023;64(4):573–584. https://doi.org/10.1111/vru.13259

Cui S, Tseng HH, Pakela J, Ten Haken RK, El Naqa I. Introduction to machine and deep learning for medical physicists. Med Phys. 2020;47(5):e127–e147. https://doi.org/10.1002/mp.14140

Fragoso-Garcia M, Wilm F, Bertram CA et al. Automated diagnosis of 7 canine skin tumors using machine learning on H&E-stained whole slide images. Vet Pathol. 2023;60(6):865–875. https://doi.org/10.1177/03009858231189205

Hennessey E, DiFazio M, Hennessey R, Cassel N. Artificial intelligence in veterinary diagnostic imaging: a literature review. Vet Radiol Ultrasound. 2022;63 Suppl 1:851–870. https://doi.org/10.1111/vru.13163

Kim E, Fischetti AJ, Sreetharan P, Weltman JG, Fox PR. Comparison of artificial intelligence to the veterinary radiologist's diagnosis of canine cardiogenic pulmonary edema. Vet Radiol Ultrasound. 2022;63(3):292–297. https://doi.org/10.1111/vru.13062

Kittichai V, Kaewthamasorn M, Thanee S et al. Classification for avian malaria parasite Plasmodium gallinaceum blood stages by using deep convolutional neural networks. Sci Rep. 2021;11(1):16919. https://doi.org/10.1038/s41598-021-96475-5

McEvoy FJ, Amigo JM. Using machine learning to classify image features from canine pelvic radiographs: evaluation of partial least squares discriminant analysis and artificial neural network models. Vet Radiol Ultrasound. 2013;54(2):122–126. https://doi.org/10.1111/vru.12003

McEvoy FJ, Proschowsky HF, Müller AV et al. Deep transfer learning can be used for the detection of hip joints in pelvis radiographs and the classification of their hip dysplasia status. Vet Radiol Ultrasound. 2021;62(4):387–393. https://doi.org/10.1111/vru.12968

Müller TR, Solano M, Tsunemi MH. Accuracy of artificial intelligence software for the detection of confirmed pleural effusion in thoracic radiographs in dogs. Vet Radiol Ultrasound. 2022;63(5):573–579. https://doi.org/10.1111/vru.13089

Nagamori Y, Sedlak RH, DeRosa A et al. Further evaluation and validation of the VETSCAN IMAGYST: in-clinic feline and canine fecal parasite detection system integrated with a deep learning algorithm. Parasit Vectors. 2021;14(1):89. https://doi.org/10.1186/s13071-021-04591-y

Ng AY, Oberije CJG, Ambrózay É et al. Prospective implementation of AI-assisted screen reading to improve early detection of breast cancer. Nat Med. 2023;29(12):3044–3049. https://doi.org/10.1038/s41591-023-02625-9

Norman C, Stavisky J, Westgarth C. Importing rescue dogs into the UK: reasons, methods and welfare considerations. Vet Rec. 2020;186(8):248. https://doi.org/10.1136/vr.105380

Paslı S, Şahin AS, Beşer MF, Topçuoğlu H, Yadigaroğlu M, İmamoğlu M. Assessing the precision of artificial intelligence in ED triage decisions: insights from a study with ChatGPT. Am J Emerg Med. 2024;78:170–175. https://doi.org/10.1016/j.ajem.2024.01.037

Pijnacker T, Bartels R, van Leeuwen M, Teske E. Identification of parameters and formulation of a statistical and machine learning model to identify Babesia canis infections in dogs using available ADVIA hematology analyzer data. Parasit Vectors. 2022;15(1):41. https://doi.org/10.1186/s13071-022-05163-4

Raza MM, Venkatesh KP, Kvedar JC. Generative AI and large language models in health care: pathways to implementation. NPJ Digit Med. 2024;7(1):62. https://doi.org/10.1038/s41746-023-00988-4

Reagan KL, Reagan BA, Gilor C. Machine learning algorithm as a diagnostic tool for hypoadrenocorticism in dogs. Domest Anim Endocrinol. 2020;72:106396. https://doi.org/10.1016/j.domaniend.2019.106396

Sharma A, Virmani T, Pathak V et al. Artificial intelligence-based data-driven strategy to accelerate research, development, and clinical trials of COVID vaccine. Biomed Res Int. 2022;2022:7205241. https://doi.org/10.1155/2022/7205241

Siegle RL, Baram EM, Reuter SR, Clarke EA, Lancaster JL, McMahan CA. Rates of disagreement in imaging interpretation in a group of community hospitals. Acad Radiol. 1998;5(3):148–154. https://doi.org/10.1016/s1076-6332(98)80277-8

Spiteri M, Knowler SP, Rusbridge C, Wells K. Using machine learning to understand neuromorphological change and image-based biomarker identification in Cavalier King Charles Spaniels with Chiari-like malformation-associated pain and syringomyelia. J Vet Intern Med. 2019;33(6):2665–2674. https://doi.org/10.1111/jvim.15621

Stowell CC, Kallassy V, Lane B et al. Automated echocardiographic left ventricular dimension assessment in dogs using artificial intelligence: development and validation. J Vet Intern Med. 2024;38(2):922–930. https://doi.org/10.1111/jvim.17012

Sun L, Yin C, Xu Q, Zhao W. Artificial intelligence for healthcare and medical education: a systematic review. Am J Transl Res. 2023;15(7):4820–4828.

Vasilatis DM, Cowgill LD, Farace G, Peterson S, Yerramilli M, Owens SD. Comparison of IDEXX SediVue Dx® urine sediment analyzer to manual microscopy for detection of casts in canine urine. J Vet Intern Med. 2021;35(3):1439–1447. https://doi.org/10.1111/jvim.16090

Zuraw A, Aeffner F. Whole-slide imaging, tissue image analysis, and artificial intelligence in veterinary pathology: an updated introduction and review. Vet Pathol. 2022;59(1):6–25. https://doi.org/10.1177/03009858211040484


UK-VET
The Veterinary Nurse
The practical CPD journal for veterinary nurses
UK-VET The Veterinary Nurse
Practical international peer-reviewed journal
ukvet.co.uk
Editorial
For the love of education
Education
The use of an evidence-based approach for teaching student veterinary nurses during workplace anaesthesia training. Part 1
Clinical
Otitis externa: the role of the veterinary nurse
Zoonotic parasite protection in the practice setting
Canine immune-mediated haemolytic anaemia part 1
Practical
How to set up for dental extractions
Patient care report
Extended patient care report for a patient in anaphylactic shock
Research
Does body condition scoring portray an accurate representation of a horse's condition when compared to other morphological techniques?
Comment
Ensuring there is not a dry eye in the house
Research | Letters | CPD | Jobs
Subscribe from £10.25 per month
The Veterinary Nurse delivers high-quality, peer-reviewed practical articles to assist veterinary nurses in daily practice.
Written and reviewed by expert practitioners, it covers every clinical topic of relevance, such as nutrition, pharmacology and critical care, and every species you are likely to encounter - large, small and exotic; it is the professional resource for clinical expertise, best practice and continued professional development.
SUBSCRIBE TODAY: www.theveterinarynurse.com 0800 137 201
Includes 30-day money-back guarantee. Monthly subscriptions start from £10.25. Annual subscriptions start from £103.00.
Online subscriptions include access to UK-VET CPD. P&P included for UK-based subscribers only.


UK-VET Companion animal
The practical CPD journal for small animal vets
UK-VET Companion animal
The practical peer reviewed CPD journal for the small animal vet
ukvet.co.uk
Editorial
Are endectosides the future of parasite control?
Clinical review
Canine separation anxiety: how first referral practices can help
Vatinoxan: a new development in the clinical use of α₂-adrenoceptor agonists in dogs, part 1
Cutaneous adverse food reactions in the dog and cat: what's new?
Aflatoxicosis in dogs
Nutritional management of feline chronic enteropathy
Original research
Flea product efficacy, pet owners' adherence and treatment failure: what's the connection?
Small animal review
The safety of additives in pet food, dietary management of canine epilepsy and the use of medicinal plants in canine dermatology
Editorial | Small Animal Review | CPD | Clinical re
Subscribe from £13.25 per month
UK-VET Companion Animal is the peer-reviewed journal for small animal vets, dedicated to best practice and continuing professional development.
Written by experienced practitioners, and covering all relevant species (including exotics) and clinical areas, it is a vital resource to inform your skills and meet your CPD requirements.
SUBSCRIBE TODAY:
magsubscriptions.com/companion
0800 137 201
Includes 30-day money-back guarantee. Monthly subscriptions start from £13.25. Annual subscriptions start from £138.00.
Premium subscriptions include access to UK-VET CPD. P&P included for UK-based subscribers only.