

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.

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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 in practice, 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 (Pashl 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 intel-

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.

ligence, 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-

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

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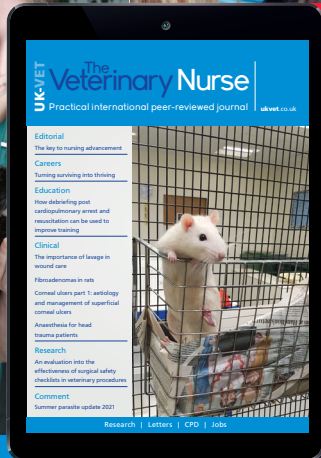
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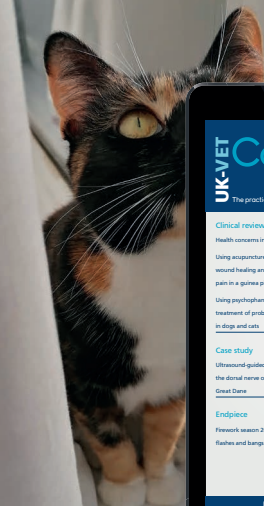
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