# Advancements and Future Directions in Ornamental Birds Radiology: Integrating High-Resolution Digital Imaging, Artificial Intelligence, and Three-Dimensional Modalities

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## ABSTRACT

***Background/Objective:*** *Ornamental birds have always posed special diagnostic challenges in veterinary medicine due to their unique physiological characteristics, small size, and high sensitivity. Radiology, as one of the main diagnostic tools, plays a vital role in identifying skeletal, respiratory, and gastrointestinal diseases in these animals. However, the limitations of conventional radiographic techniques have highlighted the need to develop more accurate and less invasive methods. This review aims to systematically assess future developments in radiology for ornamental birds, with a focus on emerging technologies and a roadmap for enhancing diagnostic accuracy.*

***Methodology:*** *This study was conducted as a systematic review by searching reputable scientific databases, including PubMed, Scopus, and Web of Science. Keywords used included "avian radiology", "diagnostic imaging", "ornamental birds", "digital radiography", "CT scan", and "artificial intelligence". The inclusion criteria for studies were a focus on advanced imaging technologies and their application in avian medicine during the period from 2010 to 2024. Relevant data were extracted, categorized, and qualitatively analyzed.*

***Results:*** *The analysis of studies suggests that the future of radiology in ornamental birds will be based on A complete transition to digital, replacing traditional methods with high-resolution digital radiography systems, which will significantly reduce radiation dose, improve image quality, and enable digital processing. The increasing use of 3D modalities, such as computed tomography (CT) and especially micro-CT, has established itself as the gold standard for diagnosing delicate fractures, sinus diseases, and internal abnormalities, due to their ability to provide exceptionally detailed cross-sectional images of the complex anatomy of birds. AI algorithms can automatically evaluate radiographic images, detect aberrant patterns (such as pneumonia and stratum corneum dilatation) with high accuracy, and serve as an assistant to veterinarians. This is accomplished through the integration of artificial intelligence (AI) with diagnostic software, resulting in a decrease in the number of mistakes caused by humans and a uniformity in the interpretation of images.*

***Conclusion:*** *The future of radiography in ornamental birds is going to be technologically advanced, three-dimensional, and AI. The convergence of these technologies will not only increase diagnostic accuracy to an unprecedented degree but also make it possible to screen for diseases early, plan surgical procedures with greater precision, and ultimately improve the quality of life for these birds. Additionally, it is vital to invest in the training of veterinarians to utilize these technologies and develop specialized imaging techniques for small birds as the next step in this approach.*

***Keywords:*** *Ornamental avian radiology, diagnostic imaging, computed tomography (CT), artificial intelligence, digital radiography.*

## 1. INTRODUCTION

In many households, ornamental birds hold a unique position not only as companions but also as treasured family members [1]. Passeriform birds range from the well-known cockatiels and colorful parrots to the delicate finches [2]. The inherent limitations in communication and illness diagnosis, on the other hand, are one of the most serious issues that emerge in the field of medicine regarding passeriform birds [3]. Birds have a strong desire to conceal symptoms of weakness and disease, as this, in the wild, makes them more susceptible to predators [4]. This is because birds have a survival instinct that drives them to behave in this manner. This condition, which is referred to as "disease concealment," often results in the owner not being aware of the issue until the illness has progressed to a level that is both advanced and more dangerous. As a result, veterinarians often encounter patients who have lost the window of opportunity for early treatment, and the need for diagnostic instruments that are both robust and rapid is greater than ever.

Radiology, often known as radiography, is one of the imaging procedures that has been at the forefront of veterinary diagnosis for many years [5]. It is also one of the most fundamental and easily available imaging techniques. Having the capability to observe internal structures, such as bones, the respiratory system, and viscera, in a non-invasive manner provides essential information about fractures, the presence of foreign bodies, the size of the heart and liver, and indicators of pneumonia [6-8] (Figure 1). In contrast, traditional radiography, which utilizes film or early digital systems, faces inherent difficulties when applied to the area of ornamental birds [9]. The small size of anatomical structures, the complex shadowing of organs on each other due to the body's compactness, and the requirement for extremely low radiation doses resulting from tissue sensitivity are all examples of these limitations. It is possible that a straightforward two-dimensional picture may not be able to highlight a primary mass in the kidney or a minor lesion located amid the strong bones of the coracoid [10].

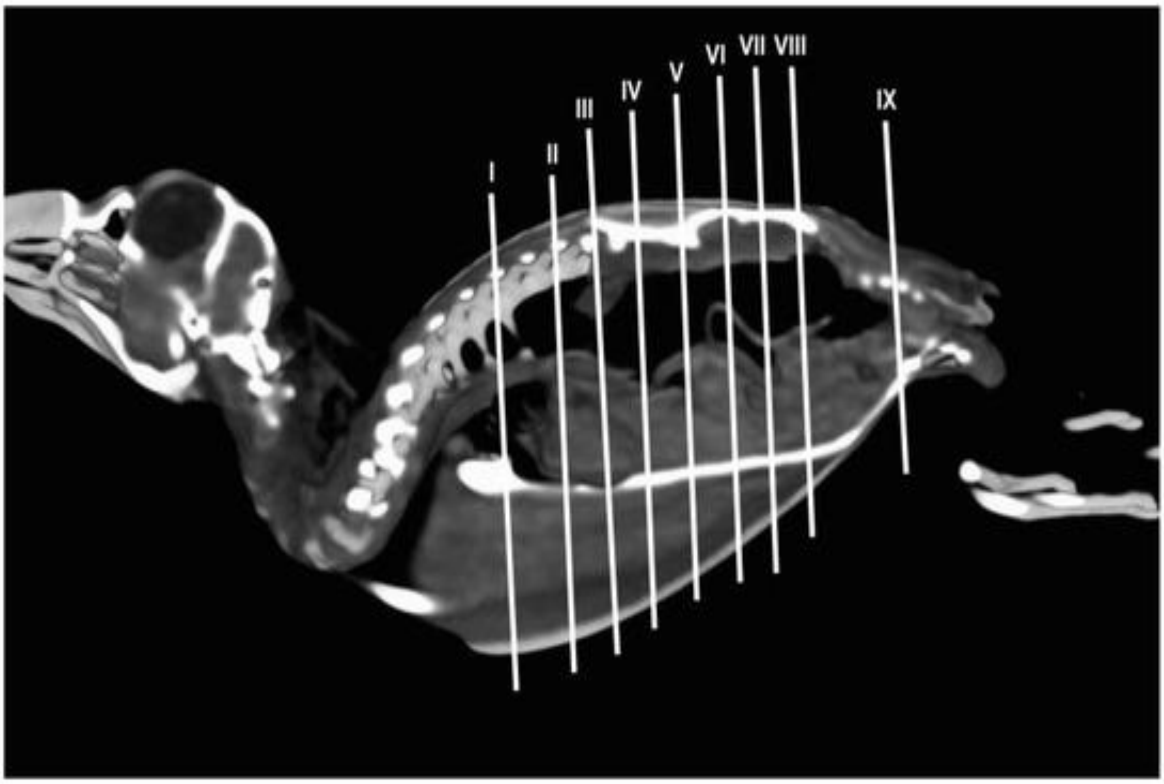


Figure 1. Sagittal MPR volume rendering image of the body of an Atlantic puffin. The lines and numbers (I–IX) represent the approximate level of the following transverse cross-sections and CT images [11] (MDPI copyright).

These constraints have been the primary impetus behind the development and use of increasingly advanced imaging technologies over the last several decades. Computed tomography (CT) and magnetic resonance imaging (MRI) are two examples of technologies that have revolutionized veterinary medicine, particularly in the diagnosis of illnesses [12, 13]. By providing high-resolution cross-sectional pictures, CT scanning overcomes the problem of shadowing and permits the inspection of bones and soft tissues in unprecedented detail [14]. This is made possible by the fact that CT scanning gives images. This capacity is vital when it comes to detecting complicated sinus infections, subtle vertebral fractures, and intraosseous lesions, all of which are readily overlooked on conventional radiographs [15-17] (Figure 2). On the other hand, the availability of these technologies and their relatively high cost continue to be obstacles in many general clinics at this time [18-20].

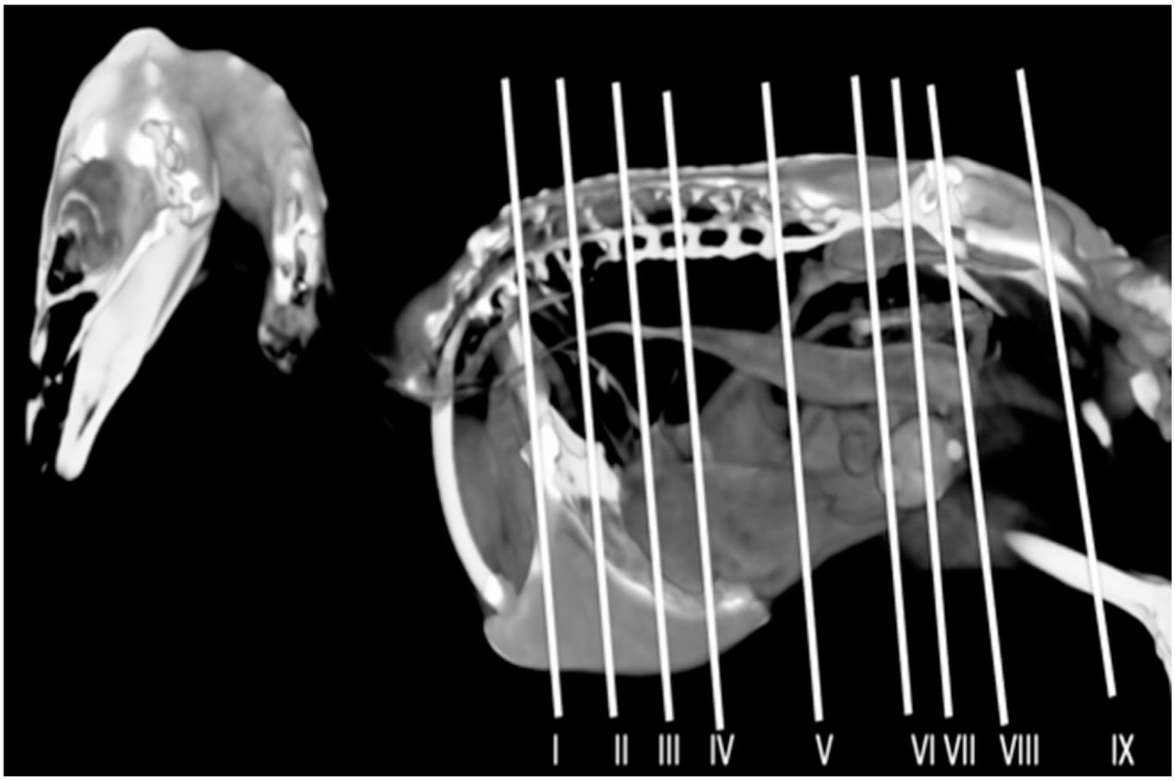


Figure 2. Sagittal MPR volume rendering image of a Cory's Shearwater specimen. The lines and corresponding numbers (I–IX) indicate the approximate positions of the subsequent transversal cross-sections and CT images [21] (MDPI Copyright).

The interpretation and analysis of radiological images are undergoing significant development, concurrent with the breakthroughs being made in technology. This evolution has the potential to revolutionize the system completely. The discipline of veterinary treatment for ornamental birds is on the verge of being revolutionized by the introduction of artificial intelligence (AI) and machine learning algorithms [22, 23]. As a result of training on thousands of photos of both healthy and ill cases, these technologies can recognize subtle and complicated patterns that may be concealed from even the most experienced specialists [24]. As a diagnostic aid, an artificial intelligence system may provide the veterinarian with a one percent chance of pneumonia, stratum corneum dilatation, or vascular calcification that the animal is experiencing. In addition to improving diagnostic accuracy, AI also helps standardize picture interpretation, which in turn helps reduce mistakes caused by exhaustion or inexperience [25].

Thus, avian radiology can be seen as a transition from traditional radiology to an entirely new paradigm; one in which advanced digital technologies, 3D techniques, and AI combine to elevate our understanding of the health and disease of ornamental birds to an entirely new level [26]. These developments not only mean higher accuracy but also the possibility of earlier diagnosis, more precise surgical planning, and ultimately, a more realistic prognosis and improved survival chances for these creatures. Understanding this vision and preparing for its implications is essential for the veterinary community.

This review aims to systematically review the future outlook for radiology in ornamental birds, focusing on three principal axes: digital technologies (such as ultra-high-resolution radiography), 3D imaging modalities (especially CT scanning), and the increasing role of artificial intelligence in image interpretation. The review examines how these technologies are converging to overcome current diagnostic limitations, enhance diagnostic accuracy, and ultimately outline a roadmap for standardizing and democratizing access to advanced diagnostic care for this special patient group.

## *2. METHODS AND MATERIALS*

The purpose of this research was to gather, evaluate, and synthesize the most thorough information that is currently available on novel radiological technologies in ornamental birds. The evaluation was conducted in the form of a narrative systematic review, employing a qualitative methodology. The search methodology was developed in accordance with the recommendations provided by the Preferred Reporting Items for Systematic Reviews (PRISMA) to ensure the highest possible degree of accuracy and repeatability. A first search was conducted in well-known scientific databases on a global scale. These databases included PubMed/Medline, Scopus, Web of Science (Core Collection), and Google Scholar (to include gray studies). The search period spanned from January 2010 to December 2024. This particular time range was carefully selected to encompass all the substantial and rapid advancements made in artificial intelligence and digital imaging technologies over the past decade. To achieve the highest possible level of search sensitivity while also guaranteeing that the results are as specific as possible, a tailored search strategy was implemented for each database. Boolean operators such as AND, OR, and NOT were used. Keywords were ("Diagnostic Imaging" OR "Radiography" OR "Digital Radiography" OR "X-ray" OR "Tomography, X-Ray Computed" OR "CT" OR "Computed Tomography" OR "Micro-CT" OR "Magnetic Resonance Imaging" OR "MRI") AND ("Birds" OR "Avian" OR "Psittacines" OR "Parrots" OR "Passerines" OR "Songbirds" OR "Budgerigar" OR "Cockatiel" OR "Finches" OR "Canaries" OR "Ornamental Birds" OR "Pet Birds" OR "Exotic Birds") AND ("Artificial Intelligence" OR "AI" OR "Machine Learning" OR "Deep Learning" OR "Computer-Assisted Diagnosis" OR "Image Interpretation" OR "Three-Dimensional Imaging" OR "3D Reconstruction").

After the search was performed, all records were transferred to the reference management software EndNote, and duplicates were automatically and manually removed. The screening process was conducted in two stages. In the first stage, the titles and abstracts of all studies were reviewed based on predefined criteria. Inclusion criteria included original articles, review articles, case reports, and conference proceedings that specifically addressed the use of digital radiography, CT scan, MRI, or artificial intelligence in the diagnosis of diseases in ornamental birds (parrots, ornamental songbirds, etc.). Studies that focused only on industrial birds (mallards) or other animals, as well as articles for which the full text was not available or were in a language other than English, were excluded. In the second stage, the full text of the selected articles was carefully reviewed to ensure their relevance to the research objectives.

Within the finished articles, the most important facts were extracted and then compiled into a standardized table. These data included information such as the author, the year the study was published, the type of study, the number of birds studied and the species of birds studied, the imaging technology that was used (for example, digital radiography, micro-CT, etc.), the specific clinical application (for example, the diagnosis of respiratory, skeletal, or gastrointestinal diseases), and the most important findings related to the accuracy and diagnostic benefits of the technology. It was not possible to conduct a meta-analysis because of the inherent heterogeneity in the study designs and objectives. As a result, a narrative synthesis was employed to qualitatively analyze the data, identify common themes, emerging trends, and knowledge gaps, and provide a comprehensive vision for the future of the field.

## 3. *RESULTS*

A systematic analysis of the selected articles revealed that the evolution of ornamental avian radiology is centered on three main technological pillars, each of which is significantly overcoming the limitations of traditional methods [11, 27-38]. First is the definitive transition from film-based radiography to fully digital, high-resolution systems. Several studies have shown that flat-panel digital detectors not only allow for a reduction in radiation dose without compromising image quality but also provide the radiologist with powerful diagnostic tools with post-imaging processing capabilities (such as contrast modification, digital magnification, and precise measurements). This development has been particularly revolutionary in the visualization of delicate structures such as bone trabeculae, the detection of hairline fractures, and the detection of small metallic foreign bodies in the proventriculus. Additionally, digital storage has enabled the creation of large archives and remote access to images for expert consultation.

The increasing establishment of CT as a vital diagnostic tool and, in some cases, a superior alternative to conventional radiography. There is strong evidence that CT's unique ability to produce high-resolution cross-sectional images completely overcomes the central problem of superimposition, which has long been a drawback of two-dimensional radiography in birds [21, 39-42]. Numerous case studies clearly demonstrate the superiority of CT in diagnosing complex diseases of the coelomic cavity, accurately differentiating internal viscera, accurately assessing the extent of tumors, and detecting bony lesions in the skull and spine that are completely missed on plain radiography [11, 21, 43, 44]. 3D reconstruction techniques based on CT data enable surgeons to plan surgeries with unprecedented precision, as the complex anatomy of joints and bones can be examined from any angle before surgery.

Additionally, the effective use of AI and machine learning algorithms for the automatic interpretation of radiological pictures of birds is regarded as one of the most inventive applications of these technologies. Pilot studies have demonstrated that artificial intelligence models trained on large datasets are capable of identifying common pathologies, such as pneumonia, stratum corneum dilatation, hepatomegaly (enlarged liver), and intracoelomic masses, with an accuracy that is comparable to that of experienced radiologists. This is even though this field is still in its relatively early stages. These devices not only act as a second assistant to reduce the likelihood of human mistakes, but they also offer the ability to standardize radiological reporting and examine large quantities of images in a short amount of time in busy clinics. In addition, these algorithms have demonstrated the potential to recognize subtle quantitative patterns (Radiomics) that may be concealed from the human eye. For example, they may be able to identify early alterations in lung tissue induced by chronic fungal infections.

A key result of combining these data is the identification of a convergence trend between these three technologies. The future is moving towards integrated platforms in which high-resolution raw data from digital systems is directly processed by AI-based software to annotate suspicious areas automatically, and this data is then fed into CT software for targeted and more accurate 3D reconstruction. This convergence creates a fully optimized workflow where diagnostic accuracy is maximized, diagnostic time is minimized, and ultimately, patient prognosis is significantly improved. This new paradigm will elevate the veterinarian's role from that of a mere interpreter to that of an intelligent manager of the diagnostic system.

## 4. *DISCUSSION*

The results of this systematic review clearly demonstrate that radiology in ornamental birds is on the verge of a significant paradigm shift. The move from traditional 2D imaging [8] to an integrated, digital, and 3D diagnostic ecosystem is not just an incremental improvement, but a fundamental change in how we understand disease in these sensitive species [20, 45]. The ability of CT scanning to eliminate the problem of organ shadowing is alone one of the greatest achievements of the last decade. This technology has opened a window into the intricacies of avian anatomy that were previously inaccessible [41, 46]. Accurate diagnosis of sinus disease, realistic assessment of the spread of neoplasms in the coelomic cavity, and identification of subtle spinal lesions are now not only possible but are becoming the new standard of diagnostic care in specialized clinics. This requires redefining current diagnostic protocols and replacing many outdated procedures with these more accurate technologies.

However, the integration of AI into the interpretation process is the most controversial and yet promising aspect of this transformation. AI has tremendous potential for democratizing radiology expertise. In other words, a general veterinarian in a clinic with access to a trained AI system can interpret images more confidently and benefit from initial specialist advice. This could reduce the knowledge gap between general clinics and specialist centers. However, this potential comes with major challenges. For an AI algorithm, the amount, diversity, and quality of its training data are closely related to the quality and accuracy of the algorithm [47-51] (Figure 3). A major investment in infrastructure is required to create a comprehensive collection of standardized radiological images of ornamental birds, reliably documented and encompassing a diverse range of species. This endeavor involves international cooperation between research institutes and veterinary offices.

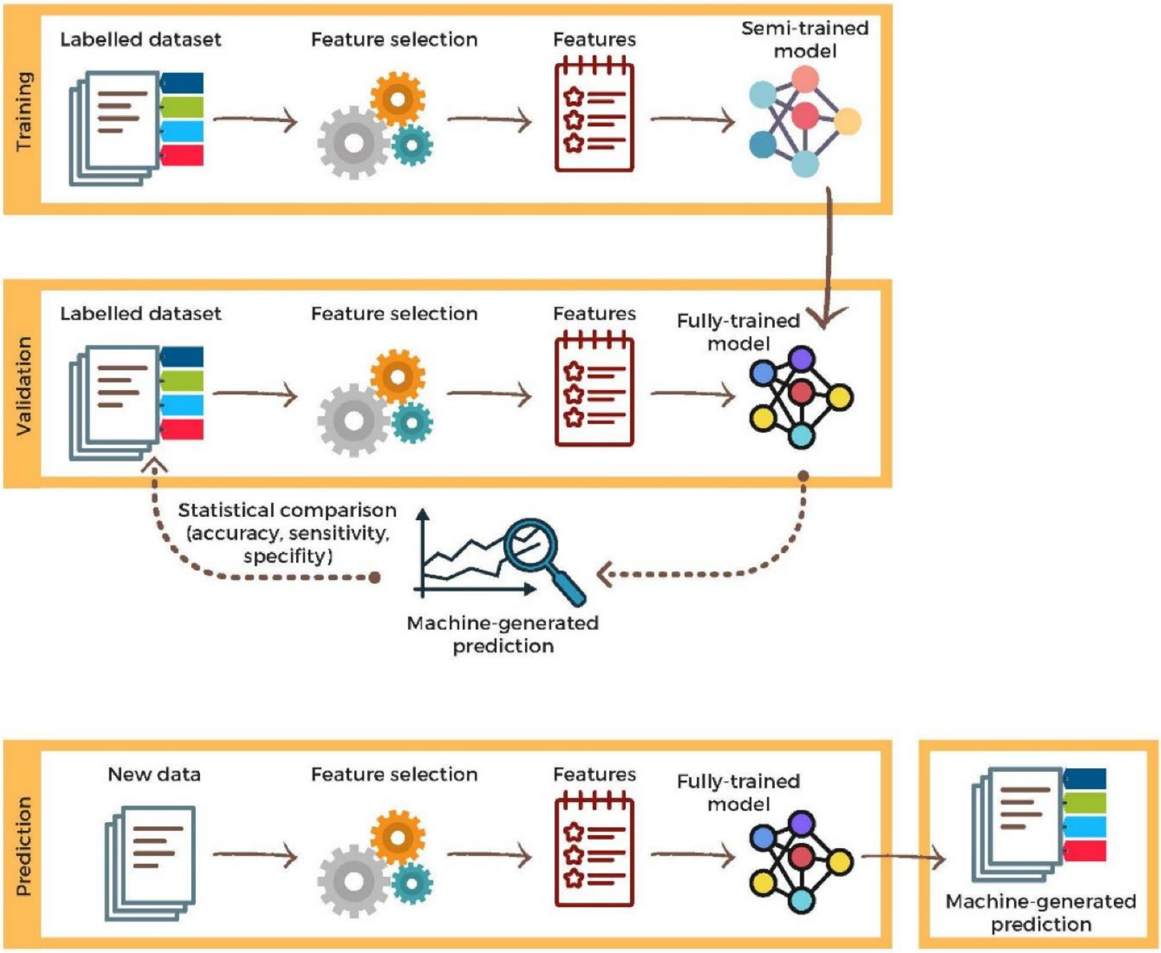


**Figure 3.** A brief description of the supervised learning flowchart, including training, validation, and prediction [50] (MDPI Copyright).

There are also other practical challenges to the widespread adoption of these technologies. The very high initial cost of purchasing and installing dedicated or high-end CT scanners, as well as the costs of maintaining and updating AI software, could pose a major barrier for many conventional veterinary clinics. These risks create a digital divide, with only academic and specialist centers in large cities having access to these technologies, and the quality of diagnostics elsewhere may remain the same. Furthermore, the need to train human resources to work with these complex systems, and in particular to critically interpret AI outputs, is an unavoidable necessity. The veterinarian should not become a "verification nut" for AI diagnoses, but should be able to evaluate, confirm, or reject their results based on clinical examination and their own knowledge.

It is anticipated that imaging technology will continue to advance, leading to further downsizing and increased mobility. Moving forward, the next significant step will be the creation of CT scanners that are more compact, less expensive, and capable of being deployed in veterinary institutions. In addition, the future holds promise for predictive artificial intelligence, which not only detects existing ailments but also analyzes micropatterns in images to forecast the likelihood of future diseases, such as the progression of osteoarthritis or congestive heart failure, thereby allowing for preventive measures. In addition, the combination of radiological data with other types of omics data, including genomes and proteomics, may open up new avenues for the practice of tailored treatment for ornamental birds.

There is no denying that the potential advantages of these innovations in terms of enhancing the quality of life for ornamental birds are clear, despite the associated financial, educational, and infrastructural constraints that currently exist. The discipline of radiology is headed toward a future in which diagnoses will be made more quickly, with more precision, and with fewer intrusive procedures. Not only is it the responsibility of the veterinary community to passively accept these changes, but it is also their responsibility to actively engage in shaping them. Within the scope of this relationship, investments will be made in research to produce trustworthy datasets. Documented training programs will be developed for general veterinarians, and ethical norms and procedures will be established for the use of AI. In this manner, will we be able to ensure that these cutting-edge technologies are used fairly and responsibly to enhance the health of all ornamental birds?

## *5. CONCLUSION*

In summary, the future of radiology in ornamental birds is a digital, 3D, and intelligent one, where the convergence of three key technologies, ultra-high-resolution digital radiography, advanced 3D imaging (particularly CT scanning), and artificial intelligence algorithms, will fundamentally transform the way diseases are diagnosed and managed. Collectively, these developments have the potential to overcome the inherent limitations of traditional radiology, including organ shadowing and interpretation difficulties, and define a completely new standard in the care of these sensitive patients by enabling earlier diagnosis, more accurate treatment and surgical planning, and ultimately a more realistic prognosis. However, fully exploiting this potential requires overcoming significant challenges, including the high cost of the technology, the risk of creating a digital divide, and the urgent need for education and training of the veterinary community. Therefore, moving towards this future requires a collective commitment to invest in research, develop infrastructure, and establish ethical standards to ensure that these remarkable advances are equitably and responsibly managed, thereby improving the health and well-being of all ornamental birds.

**Declarations and statements**

**Funding**

No funding was received to conduct this study.

**Conflict of interest**

The authors declare that they have no conflict of interest.

**Data availability**

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

**Ethical approval**

All applicable international, national, and/or institutional guidelines for writing a review paper were followed.

**Author contribution**

Conceptualization: [Hamidreza Shabani], …; Methodology: [All Authors], …; Formal analysis and investigation: [All Authors], …; Writing - original draft preparation: [All Authors]; Writing - review and editing: [Haniyeh Davasaz Irani], …; Funding acquisition: [Self-funding], …; Supervision: [Haniyeh Davasaz Irani].

**Consent to participate**

Not applicable

**Consent for publication**

Not applicable

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**Declaration of the use of generative AI**

Not used.

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