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Animal dental radiology in Taiwan: The viewpoints from a senior medical radiation technologist participating in the practice of dental radiographic imaging of the giant pandas in Taipei Zoo

KEYWORDS
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The modern dentistry has historically benefited from the animal model research. Clearly, many modern procedures and medications would not exist without the help of animal experiments. Interestingly, as human dentistry developed directly from this assistance, veterinary dentistry also developed indirectly through the achievements of human dentistry.[1,2] The most obvious example is the animal dental radiology (ADR) or veterinary dental radiology (VDR) directly benefiting from the development of human dental radiology (HDR). Oral radiography using dental films has been used in veterinary medicine for decades, while digital systems for oral radiography have been developed in human dentistry and have been adapted for veterinary patients.[3] In fact, Taiwan's ADR has also developed along the same trajectory. In this article, we attempted to explore an overview of the ADR in Taiwan through an interview with a very senior and highly experienced medical radiation technologist (MRT) who was involved in the practice of dental radiographic imaging of the giant pandas in Taipei Zoo.

In this study, we used purposeful sampling to select a MRT who had extensive experience in the career of HDR to conduct an interview with him. Our questions for the MRT and his answers during the interview are shown in Table 1. The interview outline had 6 major items related to the ADR in Taiwan, including (A) the working experience of this interviewed MRT, (B) the definition of the ADR and related laws and regulations in Taiwan, (C) overview of the animal X-ray equipment in Taiwan, (D) the systems related to the ADR in Taiwan, (E) the characteristics of the ADR in Taiwan, and (F) the future development of the ADR in Taiwan.

This interviewed MRT started his medical radiology (including dental radiology) career since 1992. So far, he has been in this career for more than 30 consecutive years. According to his viewpoint, the ADR is a science and technology that applies dental radiology to the evaluation and diagnosis of the structure, function, and diseases of animal oral cavity, jawbone, and teeth. The scope of ADR application includes pets (mainly), wild conservation animals, economic animals, and other animals. The ADR is not only a branch of veterinary medicine, but also a branch of dental radiology. In Taiwan, the management of X-ray equipment and operating personnel is regulated by the Ionizing Radiation Protection Act, and the Nuclear Safety Commission (NSC) is the competent authority. According to the ionizing radiation protection regulatory system, the personnel operating medical or animal X-ray machines

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Table 1 The questions for the senior medical radiation technologist (MRT) participating in the practice of dental radiographic imaging of the giant pandas in Taipei Zoo and his answers during the interview in this study.

	The questions for the senior MRT and his answers
A	**The working experience of this interviewed MRT**
1	How many years have you worked in the medical radiology (including the dental radiology)? I started to work as a MRT in the Department of Radiology of Taipei MacKay Memorial Hospital in August 1992. Later, I changed my career path and worked in the Department of Dentistry of National Taiwan University Hospital (NTUH) in June 1996, specializing in dental radiology. Therefore, I have more than 30 years of working experience in the medical radiology.
2	How was your experience participating in the animal dental radiology (ADR) work in Taipei Zoo? I have participated in the ADR work in Taipei Zoo 4 times in total. The first time involved the Formosan black bear as the subject for simulating and developing a suitable dental radiology workflow for the conservation animals. Later, based on this experience, we successfully completed two giant pandas' full-mouth periapical radiographic examinations and one giant panda's periapical radiographic examination before and after the root canal treatment.
3	Did you have any other working experience related to the ADR? Yes, I was invited by the Taiwan College of Veterinary Surgeon (TCVS) to teach dental digital X-ray courses in the continuing education for veterinarians.
B	**The definition of the ADR and related laws and regulations in Taiwan**
4	How do you personally define the ADR? The ADR is a science and technology that applies dental radiology to the evaluation and diagnosis of the structure, function and diseases of animal oral cavity, jawbone, and teeth. The scope of ADR application includes pets (mainly), wild conservation animals, economic animals, and other animals. The ADR is not only a branch of veterinary medicine, but also a branch of dental radiology.
5	Currently, what are the legal regulations or qualifications for taking radiographs (including dental radiographs) in Taiwan? Currently, the management of X-ray equipment and the personnel operating X-ray equipment in Taiwan is regulated by the Ionizing Radiation Protection Act, and the Nuclear Safety Commission (NSC) is the competent authority. The X-ray machines are equipment capable of producing ionizing radiation (or ionizing radiation equipment), and ionizing radiation equipment is divided into equipment for human use (human medical purpose) and equipment for non-human use (including for animal use). The personnel operating ionizing radiation equipment should undergo the 18-h radiation protection training course and pass the subsequent qualification test (both are authorized by the competent authority) to get a radiation safety certificate. However, the ADR is also regulated by this legal system.
6	Currently, what are the legal regulations or qualifications regarding the management of animal X-ray equipment (including animal dental radiographic equipment) in Taiwan? The animal X-ray equipment is mainly installed in the veterinary animal care facilities (such as zoo veterinary rooms, animal hospitals, and animal clinics). The animal X-ray equipment is also regulated by the NSC and is the equipment for non-human use. The management of X-ray equipment is based on the actual objects used, not whether the equipment is a human model or an animal model. The animal X-ray equipment requires a radiation safety test report when installed. Moreover, the radiation safety test reports should be made every five years. The X-ray machines in the veterinary animal care facilities are for non-human use. Therefore, in the veterinary animal care facilities, even dental X-ray machines of human model should provide the radiation safety test reports of non-human use because they are used on animals.
7	What are the similarities and differences in Taiwan's current laws and regulations regarding the personnel operating medical and animal X-ray equipment? Similarities: According to the ionizing radiation protection regulatory system, the personnel operating X-ray machines for human use or non-human use should undergo the 18-h radiation protection training course approved by the competent authority. Difference: According to the medical-related regulatory system, those operating medical X-ray machines for human use must be physicians or MRTs, while those operating dental X-ray machines for human use must be dentists or MRTs. However, in the veterinary-related regulatory system, there is no restriction that the personnel operating X-ray machines for animal use must be veterinarians.
C	**Overview of the animal X-ray equipment in Taiwan**
8	In the X-ray equipment industry, in addition to human medical X-ray machines, are there also X-ray machines (including dental X-ray machines) designed specifically for the animal model or veterinary model? Animal oral radiography using human dental films has been performed in veterinary medicine for decades. As early as the 1960s, the veterinarians began to use silver halide dental films borrowed from human dentistry. For veterinarians, current development is to install dental X-ray machines in animal dental treatment areas. There are also dental x-ray machines designed specifically for animals. In addition to dental X-ray machines for periapical radiography, there are also cone-beam computed tomography (CBCT) specifically for animals. Over the past two decades, digital systems for oral radiography have been developed in human dentistry and have also been adapted to the veterinary patients.

(*continued on next page*)

Table 1 (*continued*)

	The questions for the senior MRT and his answers
9	In Taiwan, how do the veterinary animal care facilities use equipment for taking animal radiographs (including dental radiographs)? As far as I know, the current situation in Taiwan is that the veterinary animal care facilities usually use intraoral dental X-ray machines of human model to take dental radiographs for pets (such as cats and dogs), while medical X-ray machines of human model are used for taking radiographs of the whole body and limbs of the animal. However, X-ray machines of animal model (for animal use only) are rare in Taiwan.
D	**The systems related to the ADR in Taiwan**
10	Currently, what are the main occupations engaged in the ADR work in Taiwan? Taiwan implemented an animal medical assistant (so-called veterinary assistant) system managed by the Ministry of Agriculture in 2023, which does not restrict the behavior of veterinary assistants in taking radiographs for the animals. Therefore, in addition to veterinarians, veterinary assistants may play an important role in the ADR work in animal hospitals or animal clinics where have veterinary dentistry. However, it is rare for a MRT to be invited or hired in a zoo to assist in taking dental radiographs for the conservation animals.
11	Currently, what are the ADR-related training courses in Taiwan? Currently, Taiwan's veterinary schools have teachers with expertise in veterinary dentistry and have veterinary dental X-ray machines as the teaching equipment. The ADR-related training courses are covered under other veterinary courses. The veterinary students have the opportunity to learn ADR-related knowledge in the undergraduate courses. The veterinary professional groups (such as Taiwan College of veterinary surgeons or TCVS) offer the advanced ADR continuing education courses to veterinarians and other professionals interested in the ADR. In addition, veterinarians and veterinary assistants in the veterinary animal care facilities with dentistry can usually receive an on-the-job ADR-related training for operational practice in the workplace.
12	Does Taiwan currently have the ADR-related certification system? Currently, Taiwan has not yet developed a licensing system specifically for the ADR. The government or private entities have not set up the so-called ADR licensing system.
E	**The characteristics of the ADR in Taiwan**
13	Based on your experience, what are the types of the ADR applications in Taiwan? At present, it seems that there are two main types of the ADR applications, including (1) diagnosis and evaluation of oral and dental diseases of the conservation animals before and after treatment in zoos, and the establishment of a dental image database for the conservation animals and related academic research, as well as (2) diagnosis and evaluation of pets' oral and dental diseases before and after treatment in the veterinary animal care facilities.
14	What is the current situation of the ADR system in Taiwan? Taiwan's ADR system can be viewed from the following aspects: (1) ADR education: Currently, undergraduate education related to the ADR includes veterinary schools, dental schools, and medical radiology schools. However, this professional field belongs to the category of veterinary medicine. Among domestic undergraduate courses, the ADR learning topics in veterinary schools are usually included in other veterinary courses. There are no ADR-relevant courses in dental schools and medical radiology schools. In addition, domestic veterinary-related professional groups provide the advanced ADR courses to veterinarians or other professionals for further education or continuing education. (2) Licensing system for the ADR: There is currently no exclusive licensing system for the ADR in Taiwan. According to the regulations of the NSC, the personnel operating ionizing radiation equipment must receive the 18-h radiation protection training course. Therefore, the personnel operating animal X-ray machines must complete such training. In addition to this, there are no other restrictions. (3) Operators of animal dental X-ray machines: The Taipei Zoo Veterinary Room adopts anthropomorphic medical standards for its conservation animals, and its animal dental X-ray machines are operated by a senior MRT. At present, most of animal dental X-ray machines in the veterinary animal care facilities are operated by veterinarians themselves or assisted by veterinary assistants. (4) Types of X-ray machines used in animals: At present, in our veterinary animal care facilities, the radiographic images of animal or pet teeth are mostly taken by the intraoral dental X-ray machines of the human-model, while those of the whole body and limbs of animals or pets are mostly taken by the medical X-ray machines of the human-model (including computed tomography). The Taipei Zoo and many animal hospitals have completed the construction of digital X-ray imaging systems.
F	**The future development of the ADR in Taiwan**
15	In the field of the ADR, in addition to veterinarians, what role do you consider that human dentists and MRTs can play? According to Taiwan's Veterinarian Act, animal medical treatment is the exclusive business of veterinarians. As long as it does not involve animal medical treatment, dentists and MRTs with the professional training and relevant knowledge in oral structure and radiation technology, respectively, can participate in the ADR academic research and ADR-related education and training activities, which in turn contribute to the ADR academic development and the research on animal oral medicine.

Table 1 (*continued*)

	The questions for the senior MRT and his answers
16	What are your thoughts on the future of the ADR? Nowadays, many veterinary animal care facilities in Taiwan advertise veterinary dentistry. There are already dental X-ray machines produced specifically for animals in the world, while Taiwan already has veterinarians who perform dental implants on cats and dogs. Therefore, in addition to the animal X-ray machines for the periapical radiography, the demand of the CBCT specifically for animals will also increase. The technical complexity and expertise required for the animal or veterinary dental radiology (ADR or VDR) may be as high as those for human dental radiology (HDR). However, in our veterinary, dental, and radiological education, there are few or no courses for the ADR or VDR. Currently, relevant laws and regulations in Taiwan allow anyone who has received the 18-h radiation protection training to operate the animal X-ray machines. Given the highly professional nature of the ADR or VDR, it seems more appropriate for professionally trained veterinarians, veterinary assistants, dentists, and MRTs to perform this work. In the future, it is desirable to plan the ADR or VDR courses in veterinary, dental, and radiological education, and there is also a need to develop the ADR-related course standards or course systems.

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Currently, Taiwan has not yet developed a licensing system specifically for the ADR. The government or private entities have not set up a so-called ADR licensing system. Besides, veterinarians and veterinary assistants in the veterinary animal care facilities with dentistry can usually receive an on-the-job ADR-related training for operational practice in the workplace. In addition to veterinarians, veterinary assistants also play an important role in the ADR work in the veterinary animal care facilities in Taiwan. However, it is rare for a MRT to be invited or hired to a zoo to assist in taking dental X-rays for the conservation animals. At present, there are two main types of ADR applications, including (1) diagnosis and evaluation of oral and dental diseases of the conservation animals before and after treatment in zoos, and the establishment of a dental image database for the conservation animals and related academic research, as well as (2) diagnosis and evaluation of pets' oral and dental diseases before and after treatment in the veterinary animal care facilities.

According to Taiwan's Veterinarian Act, animal medical treatment is the exclusive business of veterinarians. As long as it does not involve animal medical treatment, dentists and MRTs with the professional training and relevant knowledge in oral structure and radiation technology, respectively, can participate in the ADR academic research and ADR-related education and training activities, which in turn contribute to the ADR academic development and the research on animal oral medicine. The technical complexity and expertise required for the ADR or VDR may be as high as those for the HDR. However, in our veterinary, dental, and radiological education, there are few or no courses on the ADR or VDR. Currently, the relevant laws and regulations in Taiwan allow anyone who has received the 18-h radiation protection training to operate the animal X-ray machines. Given the highly professional nature of the ADR or VDR, it seems more appropriate for professionally trained veterinarians, veterinary assistants, dentists, and MRTs to perform this work. In the future, it is desirable to plan the ADR or VDR courses in veterinary, dental, and radiological education, and there is a need to develop the ADR-related course standards or course systems.

Previous researches have rarely linked the ADR with human medicine. This article tried to explore an overview of the ADR in Taiwan. Among members related to the ADR in Taiwan, in addition to veterinarians, the careers of dentists and MRTs have the well-established cultivated education system and are certified by the government.[4] The ADR has long been a knowledge system. The significance of this article is to outline the current landscape of the ADR in Taiwan from the viewpoints of a senior MRT, showing that the ADR is an interdisciplinary discipline that covers veterinary medicine, human dentistry, and medial radiation. The medical model of collaboration with the ADR for animal oral health care is a good demonstration.[2]

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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None.

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