Computed tomographic anatomy of the heads of blue-and-gold macaws (Ara ararauna), African grey parrots (Psittacus erithacus), and monk parakeets (Myiopsitta monachus)

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OBJECTIVE  
To create an atlas of the normal CT anatomy of the head of blue-and-gold macaws (Ara ararauna), African grey parrots (Psittacus erithacus), and monk parakeets (Myiopsitta monachus).

ANIMALS  
3 blue-and-gold macaws, 5 African grey parrots, and 6 monk parakeets and cadavers of 4 adult blue-and-gold macaws, 4 adult African grey parrots, and 7 monk parakeets.

PROCEDURES  
Contrast-enhanced CT imaging of the head of the live birds was performed with a 4-multidetector-row CT scanner. Cadaveric specimens were stored at –20°C until completely frozen, and each head was then sliced at 5-mm intervals to create reference cross sections. Frozen cross sections were cleaned with water and photographed on both sides. Anatomic structures within each head were identified with the aid of the available literature, labeled first on anatomic photographs, and then matched to and labeled on corresponding CT images. The best CT reconstruction filter, window width, and window level for obtaining diagnostic images of each structure were also identified.

RESULTS  
Most of the clinically relevant structures of the head were identified in both the cross-sectional photographs and corresponding CT images. Optimal visibility of the bony structures was achieved via CT with a standard soft tissue filter and pulmonary window. The use of contrast medium allowed a thorough evaluation of the soft tissues.

CONCLUSIONS AND CLINICAL RELEVANCE  
The labeled CT images and photographs of anatomic structures of the heads of common pet parrot species created in this study may be useful as an atlas to aid interpretation of images obtained with any imaging modality.  

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anatomy of structures of the head is unavailable for parrot species.

The purpose of the study reported here was to develop a series of images of the normal cross-sectional anatomy (evaluated through various dissection planes) and corresponding contrast-enhanced CT features of the head in 3 common pet parrot species: blue-and-gold macaw (Ara ararauna), African grey parrot (Psittacus erithacus), and monk parakeet (Myiopsitta monachus). A secondary aim was to summarize the most appropriate window width and window level settings (window) as well as the CT reconstruction kernels (filter) with which to evaluate various structures or organs of the head.

Materials and Methods

Animals

For the CT portion of the study, 3 live blue-and-gold macaws (2 males and 1 female; mean ± SE body weight, 1,002 ± 16 g; mean body length, 85 ± 3 cm), 5 African grey parrots (3 males and 2 females; mean body weight, 369 ± 7 g; mean body length, 34.5 ± 2 cm), and 6 monk parakeets (3 males and 3 females; mean body weight, 129 ± 3 g; mean body length, 29 ± 1 cm) that were brought to the Veterinary Teaching Hospital of the University of Padova in Padua, Italy, from May 2015 through August 2015 were enrolled. The birds had been part of a study of the prevalence of subclinical airway infections in captivity-kept parrots. All had undergone CT examination of the entire body as part of their diagnostic work-up, and no lesions of the head were identified. This study was carried out with the approval of the University of Padua Ethical Committee (protocol No. 116052). Written owner consent was obtained for each bird.

For the anatomic evaluation portion of the study, the cadavers of 4 adult blue-and-gold macaws (1 male and 3 female; mean ± SE body weight, 1,000 ± 15 g; mean body length, 84 ± 2 cm), 4 adult African grey parrots (2 male and 2 female; mean body weight, 346 ± 4 g; mean body length, 33 ± 1.5 cm), and 7 monk parakeets (3 male and 4 female; mean body weight, 128 ± 2 g; mean body length, 28.5 ± 0.5 cm) were used. All cadavers had been donated by owners to the Veterinary Teaching Hospital of the University of Padova or to the Clinic for Exotic Animals in Rome, Italy. The birds had been referred to these institutions from September 2014 through August 2015 for specialty examination and had died soon after hospitalization or had been euthanized because of advanced medical conditions. Eight birds had had hepatic insufficiency, 4 had had egg retention, and 3 had had renal failure; none of these diseases directly involved the head. Cadavers were stored immediately after death at ~20°C, in the same position as the live birds were positioned during CT examination, until completely frozen (48 to 72 hours, depending on size).

CT imaging

Each bird was anesthetized for CT examination with sevoflurane and oxygen delivered via a face mask. The trachea was then intubated with an appropriate endotracheal tube, and anesthesia was maintained with sevoflurane carried by a mixture of air and oxygen.

Birds were positioned in a prone position and kept still by means of a foam cradle. Imaging was performed in a craniocaudal direction by use of a 4-multi-detector-row CT scanner in helical acquisition mode, with an exposure time of 0.725 seconds, voltage of 120 kV, amperage of 150 mA, and slice thickness of 1 mm (reconstruction interval, 0.8 mm). After precontrast images were acquired, contrast medium (660 mg/kg) was injected in the right jugular vein quickly as possible.

Anatomic evaluation

Standard and contrast-enhanced CT images were reconstructed with a standard soft tissue filter with beam-hardening correction processing (setting Fc10) and a high-resolution filter for the inner ear and bones (setting Fc81) and displayed in a bone window (window length, 1,000 HU; window width, 4,000 HU), pulmonary window (window length, -500 HU; window width, 1,400 HU), and soft tissue window (window length, 40 HU; window width, 350 HU).

Labeling of CT and photographic images

Existing anatomic references were used to identify and label anatomic structures in photographs of ca-
daveric cross sections. Photographs of cross sections were then matched with the corresponding CT images, and CT images were labeled on the basis of the information provided in the corresponding photographs.

**Results**

Postcontrast CT images obtained from live parrots and photographs of anatomic cross sections obtained from cadaveric parrots were reviewed, and

![Figure 2](image_url)
representative images with the best diagnostic quality were selected (Figures 1–8). Most of the clinically relevant structures of the head were visible in both the cross sections and corresponding CT images. Generally, a high degree of correspondence between anatomic structures visible in the 2 sets of images was observed. The most useful filters and windows with which optimal visibility of the various head structures was achieved via CT were summarized (Table 1).

The thin trabeculae characterizing the avian skull were optimally visible on CT images when a standard soft tissue filter and pulmonary window were used (Figure 2). The same CT settings provided

Figure 3—Representative photographs of anatomic cross sections (A, D, and G) and matched CT images at the level of the nostrils (corresponding to line B in Figure 1) of the head of a blue-and-gold macaw (A–C), African grey parrot (D–F), and monk parakeet (G–I). The CT images were reconstructed with a high-resolution filter and displayed in a bone window (window length, 1,000 HU; window width, 4,000 HU: B, E, and H) or with a standard soft tissue filter and displayed in a soft tissue window (window length, 40 HU; window width, 350 HU: C, F, and I). 1 = Frontoparietal bone. 2 = Scleral ossicle. 3 = Vitreous chamber of the eye. 4 = Septum interorbitale. 5 = Musculi ethmomandibularis. 6 = Suborbital arch. 7 = Musculi adductor mandibulae externus ventralis. 8 = Glottis. 9 = Mandible. 10 = Ceratobranchiale. 11 = Gland of nictitating membrane. 12 = Musculi medial rectus. 13 = Infraorbital diverticulum of the infraorbital sinus. 14 = Pterygoid bone. 15 = Venter externus of musculi pterygoideus ventralis lateralis. 16 = Oral cavity. 17 = Trachea. 18 = Mandible. Do = Dorsal. R = Right. Bar = 1 cm.
clear visibility of the nostrils, operculum, infraorbital sinus, and cervicocephalic air sacs. The sinus and the air sacs were visible as air-filled spaces bordered by the adjacent structures. The nasal septum, conchae, scleral ossicles, interorbital septum, auditory meatus, and hyoid skeleton were clearly identifiable when a high-resolution filter and bone window were used (Figures 3, 4, and 6). Structures of the inner ear were visible neither in the anatomic cross sections nor in the CT scans of any of the examined parrot species (Figure 6).

A standard soft tissue filter with a soft tissue window allowed good visibility of the eyes and related structures in all examined parrot species (Figures 3 and 4). The anterior chamber was clearly distinguishable from the hyperattenuating lens in the lateralmost portion of the eye. The scleral ossicles were visible as mineral-attenuating structures in the intermediate segment. The vitreous chamber could be perceived as a semispherical structure filling most of the orbit. The retina and choroid were distinguishable as a single contrast enhancing line. The gland of the nictitating membrane was visible in both the CT images and the anatomic cross sections, whereas the lacrimal glands could not be identified. The ocular muscles were discernible in both the CT images and

Figure 4—Representative photographs of anatomic cross sections (A, D, and G) and matched CT images at the level of the nostrils (corresponding to line C in Figure 1) of the head of a blue-and-gold macaw (A–C), African grey parrot (D–F), and monk parakeet (G–I). 1 = Frontoparietal bone. 2 = Brain, frontal portion of the telencephalon. 3 = Vitreous chamber of the eye. 4 = Gland of nictitating membrane. 5 = Septum interorbitale. 6 = Venter externus of musculi pterygoideus ventralis lateralis. 7 = Jugal bone. 8 = Musculi adductor mandibulae externus ventralis. 9 = Mandible. 10 = Musculi pterygoideus ventralis lateralis. 11 = Musculi dorsal oblique. 12 = Optic nerve. 13 = Infraorbital diverticulum of the infraorbital sinus. 14 = Pterygoid bone. 15 = Oral cavity. 16 = Trachea. 17 = Ceratobranchiale. See Figure 3 for remainder of key.
the anatomic cross sections. The optic nerves were clearly visible as elongated structures running from the caudal portion of the eye to the midline of the head, where they connected to form the optic chiasm. The cerebral hemispheres, cerebellum, and medulla oblongata were distinguishable only on anatomic cross sections, and all had the same soft tissue attenuation (Figures 4–7).
Discussion

In avian species, the head is characterized by the presence of pneumatized bones that are in direct connection with the paranasal sinus and the cervicocephalic air sacs. We believe that the best CT imaging results regarding these structures were achieved by means of a pulmonary window in the present study because of the hypoattenuating nature of the trabeculae to bone when the bone window was used. Furthermore, reconstruction of CT images in a dorsal

Figure 6—Representative photographs of anatomic cross sections (A, D, and G) and matched CT images at the level of the nostrils (corresponding to line E in Figure 1) of the head of a blue-and-gold macaw (A–C), African grey parrot (D–F), and monk parakeet (G–I). 1 = Frontoparietal bone. 2 = Postorbital process. 3 = Musculi adductor mandibulae externus rostralis temporalis. 4 = Venter externus of musculi pterygoideus ventralis lateralis. 5 = Jugular vein. 6 = Esophagus. 7 = Trachea. 8 = Mandible. 9 = Brain, parietal portion. 10 = Cerebellum. 11 = Ear canal. 12 = Vertebra. 13 = Musculi intertransversarii. 14 = Musculi flexor colli medialis. 15 = Ceratobranchiale. 16 = Mandibular diverticulum of the infraorbital sinus. 17 = Musculi adductor mandibulae externus ventralis. See Figure 3 for remainder of key.
Figure 7—Representative photographs of anatomic cross sections (A, D, and G) and matched CT images at the level of the nostrils (corresponding to line F in Figure 1) of the head of a blue-and-gold macaw (A–C), African grey parrot (D–F), and monk parakeet (G–I). 1 = Brain, occipital lobe. 2 = Cerebellum. 3 = Occipital bone. 4 = Venter externus of musculi pterygoideus ventralis lateralis. 5 = Musculi flexor colli medialis. 6 = Jugular vein. 7 = Esophagus. 8 = Trachea. 9 = Medulla oblongata. 10 = Vertebra. 11 = Mandibular diverticulum of the infraorbital sinus. See Figure 3 for remainder of key.

plane enabled a more comprehensive visual examination of some complex head structures, such as the diverticula of the infraorbital sinus and the periorbital muscles and glands (Figure 8).

A parrot’s head can be affected by several pathological processes. Trauma caused by fights, household accidents, or other incidents is a common complaint of parrot owners.1 Severe mycotic or bacterial infections involving several structures of the head of pet parrots have been reported.27,28 Neoplastic diseases such as lymphosarcoma, mast cell tumor, fibroma, papilloma, hemangiosarcoma, and osteosarcoma...
originating from head structures of avian species have been reported, as have congenital disorders, such as hydrocephalus or beak deformities.

An important aspect of the anatomy of the heads of birds is the proximity of the paranasal sinus to the orbit. Sinusitis with subsequent enlargement of the paranasal sinus can cause a compression of the orbit, periocular swelling, conjunctivitis, and sometimes intraocular disease. Ultrasonographic examination is the most commonly used imaging technique to evaluate birds' intraocular structures. Nevertheless, ultrasonographic examination is limited to the ocular globe and optic nerve, and the scleral ossicles are better examined by means of CT. The combination of the 2 imaging techniques might be recommended as the most suitable option for a complete evaluation of the eye and related structures.

The matched anatomic cross sectional photographs and CT images created in the present study may serve as a useful reference for interpretation of
Table 1—List of the most useful CT reconstruction kernels (filter) and window widths and levels (window) with which diagnostic images of various anatomic structures in the heads of parrot species were obtained.

<table>
<thead>
<tr>
<th>Head structure</th>
<th>Filter</th>
<th>Window</th>
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<tbody>
<tr>
<td>Basisphenoid and parabasal bone</td>
<td>High resolution</td>
<td>Bone</td>
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<tr>
<td>Brain</td>
<td>Soft tissue</td>
<td>Soft tissue</td>
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<tr>
<td>Ceratobranchial bone</td>
<td>High resolution</td>
<td>Bone</td>
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<tr>
<td>Cerebellum</td>
<td>Soft tissue</td>
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<tr>
<td>Ear canal</td>
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<tr>
<td>Frontoparietal bone</td>
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<td>Bone</td>
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<tr>
<td>Gland of the nictitating membrane</td>
<td>Soft tissue</td>
<td>Soft tissue</td>
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<td>Glottis</td>
<td>High resolution</td>
<td>Bone</td>
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<tr>
<td>Hyoid skeleton</td>
<td>Soft tissue</td>
<td>Pulmonary</td>
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<tr>
<td>Infraorbital sinus</td>
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<td>Soft tissue</td>
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<td>Jugal bone</td>
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<td>Jugular vein</td>
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<td>Mandible</td>
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<td>Maxilla</td>
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<td>Medial nasal concha</td>
<td>Soft tissue</td>
<td>Pulmonary</td>
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<td>Esophagus</td>
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<tr>
<td>Optic chiasm</td>
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<td>Optic nerve</td>
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<td>Oral cavity</td>
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<td>Palatine bone</td>
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<td>Premaxillary bone</td>
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<tr>
<td>Pterygoid bone</td>
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<tr>
<td>Scleral ossicles</td>
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<tr>
<td>Septum interorbitale</td>
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<td>Spinal cord</td>
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<tr>
<td>Suborbital arch</td>
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<td>Tongue</td>
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<td>Trachea</td>
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<tr>
<td>Vertebral column</td>
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<td>Bone</td>
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<td>Vitreous chamber of the eye</td>
<td>Soft tissue</td>
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diagnostic images of the head of the 3 parrot species evaluated. The CT procedure used was fast and safe, and most of the clinically relevant structures could be thoroughly evaluated. Moreover, the use of a contrast medium allowed optimal visibility of the soft tissues. Findings suggested that given the complex nature of the avian head, combined with its small dimensions, CT would be the imaging technique of choice in the evaluation of lesions of the heads of birds. Findings regarding the optimal settings for CT examination of particular head structures (Table 1) also served as a reminder that assessment of anatomy and pathological characteristics via CT is dependent on optimizing acquisition algorithms, filters, and viewing parameters.

Footnotes

b. Toshiba Asteion S4, Toshiba Medical Systems Europe, Zoetermeer, South Holland, The Netherlands.
c. Optiray (350 mg/mL), Covidiem Spa, Segrate, Italy.

References