Feasibility of transesophageal echocardiography in birds without cardiac disease

Hugues Beaufrière, DrMedVet; Romain Pariaut, DrMedVet, DACVIM; Javier G. Nevarez, DVM, PhD; Thomas N. Tully, DVM, MS, DACVP

Objective—To establish a technique of transesophageal echocardiography (TEE) in birds without cardiac disease and describe the imaging planes obtained.

Design—Validation study.

Animals—18 birds including 3 pigeons (Columbia livia), 3 barred owls (Strix varia), 2 red-tailed hawks (Buteo jamaicensis), 1 goose (Anser anser), 1 mallard duck (Anas platyrhynchos), 1 Muscovy duck (Cairina moschata), 2 brown pelicans (Pelecanus occidentalis), 2 Hispaniolan Amazon parrots (Amazona ventralis), 2 red-fronted macaws (Ara rubrogenys), and 1 military macaw (Ara militaris).

Procedures—For each bird, anesthesia was induced and maintained by use of isoflurane. A pediatric, multiplane transesophageal ultrasound probe was passed into the esophagus and adjusted to the level of the heart for echocardiography. Probe positions were recorded via fluoroscopy, and associated imaging planes were described.

Results—TEE was performed successfully in all birds except the pelicans, 1 Hispaniolan Amazon parrot, and the red-fronted macaws. Five imaging planes of the heart were consistently viewed from 3 positions of the probe (identified as caudal, middle, and cranial positions relative to the cardiac silhouette). M-mode echocardiography of the left ventricle and the aortic root was performed. Color flow and spectral Doppler ultrasonographic images of in- and outflow regions were obtained. One Hispaniolan Amazon parrot died as a result of esophageal perforation.

Conclusions and Clinical Relevance—TEE examination of birds was feasible and provided a larger number of imaging planes with better resolution and details than those typically achieved via a transcoelomic approach. However, TEE should be performed with caution in psittacines. (J Am Vet Med Assoc 2010;236:540-547)

Detection of cardiovascular disease in pet birds is occurring with increasing frequency. A review of records of psittacine birds submitted for necropsy revealed that the incidence of cardiovascular lesions was 9.7%. In another study, low-grade histologic lesions were found in 99% of psittacine birds. Atherosclerosis in 11 to 17 orders of birds (depending on references and taxonomic classifications used) has been reported, with the Coraciiformes, Bucerotiformes, Struthioniformes, Falconiformes, and Accipitriformes being affected most often. Recent interest in transesophageal echocardiography in birds has resulted in reports of the technique, standardized examination protocols, and reference ranges for echocardiographic measurements in various avian species. In addition, the diagnostic potential of echocardiography in birds has been described in case reports. However, current techniques for echocardiographic examination of birds with transthoracic transducers have limitations. Only 2 imaging planes—the long-axis vertical 2-chamber view and the long-axis horizontal 4-chamber view obtained through the ventromedial and parasternal approach (in pigeons)—are routinely used. Short-axis views are usually not obtained via the transcoelomic approach in birds, except in chickens and pigeons. Standard transthoracic 2-D echocardiographic views that have been described for cats and dogs cannot be reproduced in birds. Moreover, in birds, echocardiographic examinations have been limited to 2-D measurements (B-mode) of the heart. M-mode echocardiographic examination, which is widely and routinely used in cats and dogs, has only been used in chickens, to our knowledge, and cannot be performed in other avian species. These important limitations diminish the clinical use of echocardiography in avian species. Limitations are primarily due to the position of the heart of birds within an indentation of the sternum that is laterally surrounded by the air sac system. These anatomic features do not provide adequate windows for cardiac ultrasonographic examination. Novel approaches are needed to overcome the limitations of transcoelomic echocardiography in avian species.

Transesophageal echocardiography involves use of a phased-array ultrasound transducer that is encased within the tip of a long flexible tube. In multiplane

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>TEE</th>
<th>Transesophageal echocardiography</th>
</tr>
</thead>
</table>

From the Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803. The authors thank Dr. Gordon Pirie and Sam Moran for supplying the macaws. Address correspondence to Dr. Pariaut (rpariaut@vetmed.lsu.edu).
probes, the transducer can be rotated through a 180° arc to obtain 2-D cross sections of the heart in a variety of imaging planes. Biplane probes only allow 2 positions, the transverse and longitudinal planes that correspond to the 0° and 90° angle, respectively. Depending on the functional capabilities of the equipment, the tip of the probe may also be flexed dorsoventrally and laterally. The TEE probe is typically introduced into the patient's esophagus and adjusted to the level of the heart to scan from the lumen of the esophagus and stomach. Transesophageal echocardiography is an established technique that is used in cats, dogs, and humans.21-23 Transesophageal echocardiography is an adjunct to transthoracic echocardiography. In humans, TEE is used to evaluate structures that are not adequately viewed via transthoracic imaging alone, as an intraoperative aid during cardiac surgeries, and for diagnosis of aortic atherosclerosis.21,22 This technique has also been proven to have higher accuracy for detecting cardiac sources of embolism, endocarditis, intracardiac masses, thrombi, and some congenital heart diseases than traditional methods.21,22 Furthermore, TEE is a valuable technique for the diagnosis and management of aortic diseases such as atherosclerosis, which may be applied to the diagnosis of central aortic atherosclerosis in birds. In cats and dogs, TEE is a complementary approach to transthoracic imaging and has been used intraoperatively; it is reported to provide higher-resolution views of the base of the heart.21,23-25 As development of miniaturized TEE probes expands, so do the range of their applications, particularly in pediatric cardiology.21

In birds, TEE may allow improved evaluation of cardiac structure and function, including transverse transventricular views, which cannot be obtained by use of transthoracic echocardiography. The proximity of the heart to the esophagus and proventriculus may reduce the interface of air from the air sacs. The purpose of the study reported here was to assess the feasibility of TEE in different species of birds and describe the technique and imaging planes obtained via 2-D and M-mode echocardiography.

**Materials and Methods**

**Animals**—Birds examined included 3 pigeons (Columbia livia), 3 barred owls (Strix varia), 2 red-tailed hawks (Buteo jamaicensis), 1 goose (Anser anser), 1 mallard duck (Anas platyrhynchos), 1 Muscovy duck (Cairina moschata), 2 brown pelicans (Pelecanus occidentalis), 2 Hispaniolan Amazon parrots (Amazona ventralis), 2 red-fronted macaws (Ara rubrogenys), and 1 military macaw (Ara militaris). Hispaniolan Amazon parrots were from an established colony housed at Louisiana State University, and the 3 macaws were from the Baton Rouge Zoo; the other birds were wild birds housed at the Wildlife Hospital of Louisiana School of Veterinary Medicine, Louisiana State University, to recover from noncardiac injuries. This study was approved by the Louisiana State University Institutional Animal Care and Use Committee (Hispaniolan Amazon parrots) and the Clinical Study Protocol Review Committee (macaws and wild birds), which allowed the use of the animals to evaluate the feasibility of the technique in birds.

**TEE system**—A multiplane TEE pediatric probe with a 3- to 7-MHz operating frequency range was used. The probe had M-mode, 2-D (B-mode), and pulsed, continuous, and color flow Doppler ultrasonographic capabilities. The probe length and tip dimensions were 1 m and 11 × 8 mm, respectively. The probe was equipped with a 48-element phased-array transducer that could be mechanically rotated through a 180° arc and controlled by the operator for ventroflexion and dorsoflexion of the tip. The probe was connected to an ultrasound imaging system.21

**Experimental procedure**—Food was withheld from each bird for 6 to 12 hours prior to echocardiographic imaging to prevent interference from food material. Anesthesia was induced with 5% isoflurane via a face mask. Birds were then intubated and placed in left lateral or sternal recumbency on a heating pad; anesthesia was maintained with 2% to 3% isoflurane and 100% oxygen. Additionally, birds were manually ventilated every 15 to 20 seconds during the entire procedure. Heart rate was monitored via cardiac auscultation. The TEE probe was introduced into the mouth and adjusted to the level of the heart. When a good-quality 2-D image of the heart was obtained via TEE, fluoroscopy was used to determine the location of the heart in the esophagus of birds with a crop (lateral aspect) and corresponding transverse and longitudinal echocardiographic views.

**Figure 1**—Schematic representations of the caudal positioning of the TEE probe in the esophagus of birds with a crop (lateral aspect) and corresponding transverse and longitudinal echocardiographic views. A—Drawing depicting the topographic location of the probe to obtain transverse views of the heart. B—Drawing depicting the longitudinal beam plane with the probe maintained in the caudal position illustrated in panel A. C—Drawing of a representative image of the caudal transverse view. D—Drawing of a representative image of the caudal longitudinal view. Ao = Aorta, bt = Right brachiocephalic trunk. Co = Coracoid. Cr = Crop. Es = Esophagus. Li = Liver. LV = Left ventricle. Pr = Proventriculus. RA = Right atrium. RV = Right ventricle. St = Sternum.
performed to assess the position of the transducer with the bird in left lateral recumbency, and a static fluoroscopic image was recorded. Patient positioning did not appear to have an effect on the quality of the images in the first 3 birds studied (1 barred owl, 1 goose, and 1 pigeon); therefore, birds were placed in sternal or left lateral recumbency thereafter. Transesophageal echocardiography was performed by 2 investigators (RP and HB) on each bird.

Several wild birds (2 pigeons, 1 duck, and 1 owl) for which previously diagnosed orthopedic conditions precluded their release were euthanatized under anesthesia at the end of the procedure by use of an IV injection of pentobarbital sodium with phenytoin sodium (1 mL/kg [0.45 mL/lb]). A postmortem examination of these birds was performed with emphasis on the gastrointestinal and cardiovascular systems.

To describe echocardiographic images obtained by use of TEE, we used the terminology that is typically reported.\textsuperscript{22–24} The terms right and left atrioventricular valves were selected in preference to tricuspid and mitral valves because of the specific anatomic features of avian hearts.\textsuperscript{27} Anatomic confirmation of the TEE imaging planes was made by comparison with results of other studies in cats\textsuperscript{28} and dogs\textsuperscript{29} and with findings of postmortem sectioning of the heart in euthanatized birds and the images obtained by use of color flow and spectral Doppler ultrasonography in the present study.

**Results**

Transesophageal echocardiography was performed in most birds with the exception of the pelicans, 1 Hispaniolan Amazon parrot, and the red-fronted macaws. The 18 birds ranged in weight from 0.25 to 3.8 kg (0.55 to 8.4 lb). The military macaw weighed 0.91 kg (2.0 lb). The 2 Hispaniolan Amazon parrots weighed 0.25 and 0.27 kg (0.55 and 0.59 lb), respectively. The 2 red-fronted macaws weighed 0.55 and 0.57 kg (1.2 and 1.3 lb), respectively. The probe was passed through the esophagus, with occasional difficulty encountered at the level of the thoracic inlet. The passage of the probe was less complicated in the avian species included in this study that do not have a crop, such as the goose, barred owls, and ducks. In other birds, the probe was manually guided by external palpation into the esophagus; slight dorsoflexion of the probe prevented deeper insertion into the crop. Complications were encountered with the insertion of the TEE probe in the region of the thoracic inlet in Hispaniolan Amazon parrots and at the esophageal-proventricular junction in the red-fronted macaws. After manipulation of the probe at the level of the thoracic inlet, the probe was advanced in...
one of the Hispaniolan Amazon parrots and a complete echocardiographic examination was performed; however, that Hispaniolan Amazon parrot died 2 days following the procedure as a result of medical complications caused by an esophageal perforation.

Once the probe was positioned inside the esophagus and an image of the heart was identified, the depth of the ultrasound beam, gain, and contrast of the image were adjusted to optimize the quality of the image. With the exception of occasional interference of air from air sacs in the cranial views, which was a particular problem during examination of the goose, manual ventilation did not appear to affect the echocardiographic imaging. Imaging was not possible in the pelicans and was attributed to the presence of a large amount of air between the proventriculus and the heart as observed in the fluoroscopic images. Small changes in the orientation of the transducer, flexion of the tip, and position of the probe were necessary to obtain good-quality images in individual birds. Greatest details and resolution of the echocardiographic views from the various imaging planes were obtained in the ducks.

As in similar studies in cats24 and dogs,23 TEE examination was performed in a caudal to cranial direction. Views of the avian heart in 3 positions—defined as caudal, middle, and cranial—were useful and repeatable. Transverse views of the heart were generated with a transducer angle at approximately 0°. The transducer angle was then adjusted between 60° to 120° for longitudinal views. Although a few repeatable planes were selected for evaluation, additional echocardiographic views were obtained as the transducer was guided through an angle of 180°.

Caudal position—The probe tip was placed in the lumen of the proventriculus and flexed ventrally to image the heart through the liver for obtaining cardiac views of all 15 birds examined from the caudal position (Figure 1). The transverse and longitudinal views of the left ventricle were similar to those obtained in cats24 and dogs.23 From the transverse view, caudal to cranial displacement of the probe and various degrees of ventroflexion of the probe tip provided cross-sectional images of the left ventricle at various levels. In the most apical view, only the left ventricle was observed. The more basilar views revealed the crescent-shaped right ventricle surrounding the liver for obtaining cardiac views of all 15 birds examined from the caudal position (Figure 1 and 2). By changing the angle of the transducer to 90° (+ 10°), a longitudinal view, which included the apex of the heart, was obtained (Figures 1 and 3). The liver was observed surrounding the apex of the heart.

Middle and cranial positions—With the probe tip in the neutral (straight) position, the probe was withdrawn cranially within the thoracic esophagus and placed cranial to the base of the heart (Figure 4). A longitudinal and transverse view was obtained from this middle position; at this position, a transverse view of the heart at the level of the atrioventricular valves, similar to a transthoracic 4-chamber view, was obtained (Figures 4 and 5). In this view, the muscular right atrioventricular valve was clearly visualized throughout the entire cardiac cycle. A longitudinal view was obtained in which the root of the aorta was visible and measurement of the aortic lumen was feasible (Figure 6). The root of the aorta was very prominent in the military macaw, compared with findings in other birds. Cranial TEE views were obtained by moving the probe cranially with a slight dorsiflexion of the probe tip, and a transverse view of the heart at the level of the aortic valve was obtained (Figures 4 and 7). As changing from one position to the other only required a small displacement of the probe, the longitudinal TEE view was similar to the TEE image obtained from the middle position, and these 2 positions could barely be distinguished between static fluoroscopic images. All of the described TEE views were consistently obtained in all birds, except at all positions in pelicans, at the middle position in the military macaw, and at the cranial position in the goose. In the goose that was examined, air between the heart and the thoracic esophagus (which likely originated from the interclavicular or the cranial thoracic air sacs) prevented appropriate visualization of the heart.

![Diagram of heart and esophagus](image)

Figure 4—Schematic representations of the middle and cranial positioning of the TEE probe in the esophagus of birds with a crop (lateral aspect) and corresponding transverse and longitudinal echocardiographic views. A—Drawing depicting the topographic location of the probe to obtain transverse views of the heart at the middle (1) and cranial (2) positions. B—Drawing depicting the longitudinal beam plane with the probe maintained in the middle or cranial position. C—Drawing of a representative image of the middle transverse view. D—Drawing of a representative image of the cranial transverse view. E—Drawing of a representative image of the middle or cranial longitudinal view. AoV = Aortic valve. LA = Left atrium. LAVv = Left atrioventricular valve. PA = Pulmonary artery. White arrow = Right atrioventricular valve. See Figure 1 for remainder of key.
and the aortic valve. Likewise, the middle transverse section of the heart could not be adequately viewed in the military macaw because of air interference.

**M-mode echocardiography**—The transverse view from the caudal position of the TEE probe yielded a cross section of the left ventricle similar to the right parasternal, short-axis view typically obtained via transthoracic echocardiography; such a view cannot be obtained in birds via the transcoelomic approach. Left papillary muscles were not prominent in the birds, with the exception of the ducks and the military macaw. Thus, it was not possible to accurately measure the left ventricular wall thickness and chamber dimension from a view at the level of the papillary muscles, which can be achieved via transthoracic echocardiography in mammals.19 Alternatively, the left ventricle was scanned from a transverse view from the apex to the tip of the left atrioventricular valve leaflets, and the image displaying the largest left ventricular chamber diameter was selected for measurements. M-mode echocardiography was used to obtain diastolic and systolic measurements of the left ventricular free wall, interventricular septum thickness, and the left ventricular internal diameter (Figure 8). In the longitudinal view obtained with the probe tip in the cranial position, the base of the ascending aorta was clearly visualized. Measurements of the aortic diameter and aorta wall thickness were obtained from M-mode echocardiographic images (Figure 9). On occasion, the motion of the aortic valve could be recorded during M-mode evaluation. M-mode echocardiography was selected for tissue measurement because of the ability of the technique to record images at a high frame rate, which markedly increases image resolution.

**Doppler ultrasonographic examination**—Color flow Doppler echocardiography was used to assess blood in- and outflows. Good-quality transverse views at the level of the atrioventricular valves and aortic valve were obtained with the probe tip in the middle and cranial positions (Figure 10). Spectral Doppler ultrasonography could be used to measure diastolic inflow and systolic outflow velocities at the levels of the aortic, atrioventricular, and pulmonic valves.

**Complications**—Self-limiting arrhythmia developed in some birds when the tip of the probe was ventrally flexed and pressed on the base of the heart. Postmortem examination and histologic examinations revealed an esophageal perforation at the level of the thoracic inlet in the Hispaniolan Amazon parrot that died 2 days...
after the TEE procedure. Four birds were euthanatized (2 pigeons, 1 duck, and 1 owl) because of poor prognosis for release into their natural habitat. Gross examination did not reveal any lesions of the gastrointestinal tract and cardiovascular structures. Other birds were subjectively observed daily for several weeks and did not develop any indications of gastrointestinal tract disease or adverse clinical signs such as anorexia, vomiting, regurgitation, changes in fecal droppings, and lethargy that may have been associated with the procedure.

**Discussion**

Our study revealed that TEE is feasible in birds of various sizes, but complications may also occur. This technique may be superior to the transcoelomic approach because it provides a larger number of views, better-quality images, and greater detail of valvular structures and it can be used to perform M-mode echocardiography. Transesophageal echocardiography may enable timely and more accurate diagnosis of cardiac diseases and may aid in the diagnosis of vascular diseases such as atherosclerosis in birds.

However, TEE was not feasible in psittacine birds, with the exception of the military macaw, which is one of the largest members of the family Psittacidae. The
military macaw weighed 910 g. The 2 Hispaniolan Amazon parrots weighed 250 and 265 g, respectively, and both were subsequently considered to be too small to undergo the procedure because their thoracic inlet region was too narrow to accommodate the width of the TEE probe. A computed tomographic scan that was performed on another Hispaniolan Amazon parrot of similar weight for the purpose of another study (unpublished data) revealed that the greatest interclavicular and intercoracoid distances were 13 and 14 mm, respectively. These distances were slightly larger than the width of the TEE probe (11 mm), which may explain the difficulty in passing the probe through the thoracic inlet region in the Hispaniolan Amazon parrots in the present study. In the 2 red-fronted macaws that weighed 0.55 and 0.57 kg, respectively, the inability of the operator to position the TEE probe in the lumen of the proventriculus was unexpected because similar procedures in other families of birds of comparable and smaller sizes have been performed successfully. In this type of macaw, the maximum diameter of the esophageal-proventricular sphincter may be smaller than that of similar birds in other families. The specific anatomic and topographic features of the crop in psittacines may have accounted for the increased difficulties and complications encountered. Passage of the TEE probe into the thoracic esophagus was challenging because the crop may be inadvertently introduced through the thoracic inlet with the probe.

Four probe positions are used during TEE examinations of cats, dogs, and humans; however, because of the small size of the birds and air interference in some cranial TEE views, only 3 probe positions were determined to be useful and repeatable in our study. A total of 5 views could be obtained in the birds examined during this study, whereas 9, 11, and 14 views have been reported with the same technique in cats, dogs, and humans, respectively. The views obtained via TEE in birds in the present study are comparable to the 2 views obtained with the previously described transcoelomic approach in most avian species and the 5 views obtained in pigeons.

Additionally, to our knowledge, transverse views and M-mode echocardiographic recordings of the left ventricle and aorta have not been obtained previously in birds, except in chickens. Transesophageal echocardiography may provide new options for the assessment of systolic function, left ventricular wall thickness, ventricular and atrial chamber size, and atherosclerosis in birds. The ability to measure the diameter of the aorta may also be clinically relevant in the diagnosis of atherosclerosis. Similar to the transcoelomic approach, color flow and spectral Doppler ultrasonographic applications may be used during TEE examinations of birds.

With the exception of the family Psittacidae, TEE views were consistently obtained from different families, morphotypes, and sizes of birds, indicating that this technique may be reliable in other appropriately sized avian species. Resistance against TEE probe passage may be encountered at the level of the thoracic inlet, especially in psittacines or birds that have a crop, but may be overcome by extension of the neck, knowledge of the anatomic features of the esophagus of the birds under examination, and careful palpation, manipulation, and redirection of the probe through the crop. Adequate TEE views from the cranial position may not be obtained in some individuals or families of birds (eg, Pelecanidae and large Anatidae) because of air interference from air sacs.

Despite the potential for clinical application, TEE has several limitations. The procedure is relatively noninvasive but must be performed in anesthetized birds. Therefore, the requirement for anesthesia may preclude the use of TEE in clinically unstable avian patients. Moreover, TEE is not recommended when a gastrointestinal condition is suspected. Species-dependent and interindividual variability in the diameter of the proventriculus and thoracic inlet are considerations when performing TEE in birds. Complications in humans during TEE include esophageal perforation, bleeding, arrhythmias, and patient’s intolerance of the procedure. However, the risks of complications are low in humans and even in children. In a study in 8 cats, 1 cat developed bradycardia and reversible cardiac arrest, which was hypothesized to be caused by persistent occlusion of pulmonary inflow by the TEE probe in the caudal position. Although cardiac arrest did not occur in any of the 15 birds examined via TEE, we recommend minimizing the amount of probe pressure applied against the heart in all positions in birds because the heart is smaller than it is in cats or dogs. Occasional cardiac arrhythmias that resolved when cardiac pressure from the TEE probe tip was decreased were detected in the present study. Because the probe must be passed through the beak and the region of the thoracic inlet, the use of TEE was also limited by the size of the bird. Also, image detail in birds was relatively less than the detail obtained via TEE in mammals because of the ultrasound frequency of the probe, which is designed for use in human pediatric patients (maximum frequency, 7 MHz). Image resolution may potentially be improved by use of a higher-frequency probe (>7 MHz), but that type of probe was not available at the time of our study. A smaller-sized probe may also improve the use of TEE in psittacines. Given these limitations, TEE may be considered a complementary diagnostic tool for transcoelomic echocardiography, which is noninvasive and does not require anesthesia.

The use of TEE overcomes the limitations in imaging that are often associated with the transcoelomic ultrasonographic approach. The results of the present study illustrate that a thorough echocardiographic examination with multiple views and use of M-mode, color, and spectral Doppler ultrasonography are now feasible in birds by use of the TEE technique. However, additional studies are needed to provide reference intervals necessary to interpret the results of TEE measurements. On the basis of our study results, we do not recommend the use of TEE in psittacine birds other than macaws weighing >0.9 kg (>2.0 lb). Clinical studies and case reports are needed to establish the diagnostic usefulness of the TEE technique for identifying cardiovascular disease in birds.

a. S7-3t TEE, Philips Healthcare, Andover, Mass.
b. IE 33, Philips Healthcare, Andover, Mass.
c. Beuthanasia-D, Schering-Plough Animal Health Corp, Union, NJ.
References