Use of high-resolution ultrasound as a diagnostic tool in veterinary ophthalmology

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Noninvasive visualization of the relationships between living tissues in vivo at a microscopic level is a goal of many imaging modalities. Recently, high-frequency ultrasound probes with frequencies ranging from 20 MHz (high-resolution ultrasound, HRUS) to 60 MHz (ultrasound biomicroscopy, UBM) have been developed that allow imaging at resolutions comparable to low-power microscopic views (20 to 80 μm). This represents a substantial improvement, compared with conventional 10-MHz probes that have resolutions of 300 to 400 μm. With improved image detail provided by high-frequency probes, however, tissue penetration is limited to 5 to 10 mm. This depth is especially well suited to ophthalmologic applications, because the critically important structures of the anterior segment of the eye and the peripheral portions of the retina are within this range. High-resolution ultrasound fills a niche in ophthalmology in that it allows evaluation of ocular structures that cannot be fully examined by use of slit-lamp biomicroscopy or that are obscured by opacities in the aqueous humor or vitreous humor.

Reported clinical ophthalmic applications of HRUS in human ophthalmology include evaluation of tumors and cysts in the anterior segment, scleral disease, intraocular assessment of the lens, trauma, and differentiation of the various forms of glaucoma. To our knowledge, only 1 in vivo study involving UBM in dogs has been published; that report compared examination of the iridocorneal angle by use of gonioscopy and by use of UBM. Although that study revealed the potential of UBM in determining the pathogenesis of canine glaucoma, UBM often requires heavy sedation or general anesthesia in small animal patients, and patient positioning is critical in obtaining an image. Imaging with high-resolution (20 MHz) probes does not typically require anesthesia or sedation and can be performed with the animal in almost any position. The purpose of the report presented here is to describe the clinical application of HRUS in veterinary ophthalmology.

Description of Technique

All images were obtained by use of a 20-MHz probe attached to a commercially available B-scan ultrasound machine. The uncovered mechanical transducer was covered with a latex rubber sleeve that had been carefully filled with distilled water to avoid entrapping air bubbles. Most animals were examined with manual restraint in sternal recumbency after topical administration of 0.5% proparacaine hydrochlo-
ride. One dog (case 3) required light sedation with acepromazine (0.1 mg/kg [0.045 mg/lb], IV) and was examined in lateral recumbency. Although the probe could be easily positioned to examine the superior and temporal quadrants of the eye, light sedation was required to examine the nasal quadrant of the eye in that dog.

The eyelids were manually held open, and the probe was placed directly over the cornea or sclera. To examine the peripheral portions of the cornea and sclera, iridocorneal drainage angle, iris, ciliary body, and lens, scans were obtained with the probe held perpendicular to the globe with the scan plane perpendicular to the limbus (technique 1, longitudinal position). To examine the ciliary processes, the probe was held perpendicular to the globe with the scan plane parallel to the limbus (technique 2, transverse position). These techniques resulted in an image depth of approximately 10 mm and a resolution of 75 μm axially and 90 μm laterally. When appropriate, structures were measured with the internal calipers on the ultrasound machine.

Results

Technique 1 provided an image similar to that obtained by a traditional low-power sagittal histologic section (Fig 1 and 2). The sclera, corneal epithelium, endothelium, and Descemet’s membrane were highly echogenic, whereas the corneal stroma was less echogenic, thereby allowing differentiation of the limbus. The iridocorneal angle and ciliary cleft were easily identified. The posterior epithelium of the iris was also highly echogenic. The ciliary body and processes could be easily imaged with both techniques. No complications were observed during or after performance of HRUS by use of either technique.

Five cases were selected to determine the usefulness of HRUS. A 12-year-old Quarter Horse gelding was examined because of a slowly growing red mass on the surface of the right eye of approximately 5 months’ duration (case 1). Slit-lamp biomicroscopy revealed the mass to be highly vascular, cavitated, and raised; the mass arose from the temporal limbus of the right eye and extended approximately 3 mm into the conjunctiva temporally and approximately 10 mm into the cornea axially. The depth of the lesion in the cornea could not be assessed due to the opacity of the mass, but there was no apparent intraocular extension. The remainder of the ophthalmic examination findings were normal in both eyes. Differential diagnoses included hemangiosarcoma, hemangioma, angiosarcoma, other tumors, granulation tissue, abscess, foreign body reaction, squamous cell carcinoma, papilloma, habronemiasis, and onchocerciasis. High-resolution ultrasound was performed, which revealed a hyperechoic mass that involved approximately one-third of...
the anterior portion of the cornea (Fig 3). On the basis of
this information, excisional biopsy and cryotherapy
of the surgical site were performed rather than enucle-
ation or full-thickness corneal excision with recon-
struction. The mass was identified histologically as a
hemangioma. The referring veterinarian reported no
recurrence 4 months postoperatively.

An 8-year-old spayed female Persian was referred
for evaluation of a corneal sequestrum of approximate-
ly 1 month’s duration (case 2). Slit-lamp biomicro-
scopy revealed a 7-mm-diameter black, slightly
raised plaque in the axial portion of the cornea of the
left eye (Fig 4). The full depth of the lesion in the
cornea could not be determined. Results of the remain-
der of the ophthalmic examination were normal in
both eyes. Surgical options were discussed with the
owner; however, medical treatment was initially cho-

Figure 1—High-resolution ultrasound image of a healthy eye in a
dog obtained with a 20-MHz probe. EP = Corneal epithelium. CS
= Corneal stroma. D = Descemet’s membrane. S = Sclera. LC =
Anterior lens capsule. CC = Ciliary cleft. CB = Ciliary body. I =
Iris. Scale indicates millimeters.

Figure 2—Ultrasound image of a normal canine eye obtained
Scale indicates millimeters.

Figure 3—High-resolution ultrasound image of the right eye of a
horse. Notice the mass (arrows) and normal cornea beneath the
mass (arrowheads). CS = Corneal stroma. D = Descemet’s
membrane. I = Iris. Scale indicates millimeters.

Figure 4—Photograph of the left eye of a cat. Arrows delineate
a sequestrum.
Tracin ophthalmic ointment was instituted. The owner believed that the cat did not tolerate the medication well and therefore discontinued treatment 1 week later. Ten weeks after initial evaluation, the owner chose surgical removal of the sequestrum. Preoperative HRUS revealed that the sequestrum was hyperechoic and extended to a depth of at least two-thirds of the stromal thickness (Fig 5). The owner was advised that because of the depth of the lesion, placement of adjunctive structural support, such as that provided by lamellar keratoplasty or a conjunctival pedicle flap, would likely be necessary, and that a simple keratectomy would not suffice. A keratectomy with a lamellar keratoplasty with a frozen corneal graft was performed via a described technique.15 The anterior 70% of the cornea was the most densely pigmented, and as much as 90% of the cornea was faintly pigmented. Histologic examination revealed that the anterior portion of the excised cornea was composed of degenerative collagen, whereas the deeper portion was mildly pigmented, with normal corneal stroma. The cat was routinely managed, and follow-up after surgery indicated that the cat did well without recurrence of the sequestrum.

A 2-year-old spayed female Golden Retriever was referred for evaluation of an iridal swelling in the right eye (case 3). Slit-lamp biomicroscopy revealed a mass in the peripheral nasal portion of the iris that displaced the iris anteriorly (Fig 6). A 1+ aqueous flare and 1+ anterior chamber cell count (0 = normal; 4+ = severe) was noted. An occasional pigmented cell in the anterior portion of the vitreous humor was also noted. Gonioscopy revealed that the iridocorneal drainage angle was normal, although the mass narrowed the approach to the drainage angle itself. Indirect ophthalmoscopy of the retina revealed normal findings, as did the remainder of the ophthalmic examination of both eyes. Differential diagnoses included melanocytoma of the iris, malignant melanoma of the iris, iri-
A 9-year-old spayed female mixed-breed dog was examined because of vision loss (case 5). The medical history included a diagnosis of diabetes mellitus 4 months previously; this disease was well controlled by parental administration of insulin. Initial ophthalmic examination revealed that direct and consensual pupillary light reflexes were present but sluggish, and menace responses were absent in both eyes. The left eye was mildly buphthalmic. Slit-lamp biomicroscopy revealed shallow anterior chambers in both eyes, 1+ anterior chamber flare in the right eye, 2+ anterior chamber flare in the left eye, mild corneal edema with keratic precipitates in both eyes, and complete cataracts in both lenses. Posterior synchiae and rubecosis iridis were detected in the left eye. Intraocular pressures measured by use of applanation tonometry were 12 mm Hg in the right eye and 16 mm Hg in the left eye. B-scan ultrasonography with a 10-MHz probe revealed multiple, free floating, hyperechoic vitreous opacities and hyperechogenicity of the lens in both eyes. High-resolution ultrasound (but not the traditional 10-MHz ultrasound) revealed a peripheral equatorial lens capsule disruption with extrusion of lens material in the left eye (Fig 9). The ciliary cleft also appeared collapsed, which was consistent with previous glaucoma and buphthalmia. The ruptured lens capsule was judged to be the cause of the difference in the inflammatory changes between the 2 eyes. Surgical options were discussed with the owners, and they were informed that the left eye was at increased risk for chronic inflammation and continuing glaucoma because of the ruptured lens capsule. Lensectomy would have the best chance at avoiding phacoclastic uveitis secondary to lens rupture; however, preexisting uveitis has been associated with an increased risk of postoperative complications. The owners chose not to pursue surgery; therefore, anti-inflammatory treatment was instituted.
Discriminating among various anterior segment diseases and more effectively develop therapeutic strategies. In contrast to UBM, which is performed via general anesthesia and with a 50- to 60-MHz probe, HRUS was easily performed in awake or lightly sedated animals with only topical anesthesia. Although image resolution with HRUS is not as good as that with UBM, the ability to perform HRUS in awake patients offered a number of distinct advantages over UBM in a clinical setting including reduced complications from the procedure, reduced expense, ability to perform sequential examinations minutes to hours apart, and freedom from artifactual changes in pupil size and accommodation associated with general anesthesia. Additionally, image quality with HRUS was adequate to discern the relevant anatomic structures. No adverse effects attributable to HRUS were detected, suggesting it is a safe procedure in a clinical setting.

The 20-MHz HRUS was a valuable adjunct to slit-lamp biomicroscopy in the evaluation of corneal opacification secondary to corneal sequestrum and neoplasia of the ocular surface. Typically, opacification involving the anterior portion of the cornea obscures or completely prevents direct determination of the full extent and depth to which the lesion involves the cornea. This complicates surgical planning, and often the surgeon is required to intraoperatively determine whether a simple keratectomy, full-thickness eyewall resection with a reconstructive procedure, or even enucleation is necessary. Faintly pigmented portion of the sequestrum was not apparent on the HRUS image in case 2, which correlated with the histologic appearance of degenerative collagen anteriorly, but HRUS allowed a better assessment than slit-lamp biomicroscopy. It also permitted the surgeon to determine that the tumor of the ocular surface in case 1 did not invade into the globe, and that surface treatment would likely be adequate. Estimates of the depth of corneal involvement may not be precisely accurate due to variations in the speed of sound in diseased corneal tissue versus that in normal cornea.

Iridal or ciliary body tumors and cysts are common ocular abnormalities in domestic animals. Differentiating between these entities, as well as other causes of iris displacement such as iris bombe and lens intumescence, is critical in maximizing the visual outcome and comfort of the patient. Anterior uveal tumors, although generally benign in dogs, can result in substantial ocular damage and loss of vision and are therefore usually treated by use of laser photocoagulation, iridectomy, iridocyclectomy, or enucleation. Uveal cysts, however, pose little threat to ocular health and are usually simply observed. Iris bombe can mimic extensive retroiridal cyst formation as well as ciliary body tumor. Additionally, anterior chamber shallowing because of swelling and anterior displacement of the lens can also appear clinically similar to iris bombe. The HRUS permitted these entities to be readily differentiated from each other in this case series, although at this time HRUS cannot differentiate tumors from granulomas. The HRUS also allowed explanation of the different degrees of uveitis between eyes in the dog with rupture of the lens capsule and allowed the clinician to better plan possible cataract surgery.

On the basis of the image quality of the iridocorneal angles in this case series, HRUS would also appear to be useful in elucidating the mechanisms by which the various forms of glaucoma may develop. It may also be a useful tool in investigating the mechanism by which various anti-glaucoma drugs lower intraocular pressure in domestic animals. Such critical measurements as the length, width, and area of the ciliary cleft, as well as the degree of iris-lens contact and angle opening distance, can be reliably measured with HRUS. Other potential uses include more critical evaluation of cats with slowly progressive diffuse melanoma of the iris. It has been reported that cats with diffuse iridal involvement have similar survival times as control groups, but that those tumors that involve other structures, such as the ciliary body, or have aggressive infiltration of the iris and its posterior epithelium are associated with increased mortality rates. Prior to the development of HRUS and UBM,
however, the clinician had no reliable method of determining whether these events had occurred. The HRUS may allow these cats to be more effectively monitored and maximize the time the eye is retained without increasing the risk of metastasis. Finally, HRUS may be a useful teaching aid, because the image allows the student to see the depth of a corneal ulcer or other anterior segment lesions that are difficult to view with other examination techniques.

References