CASE REPORT

Contralateral optic neuropathy and retinopathy associated with visual and afferent pupillomotor dysfunction following enucleation in six cats

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Abstract

Purpose To investigate contralateral optic neuropathy and retinopathy following enucleation in 6 cats.

Methods Retrospective study. The medical records of cats with contralateral visual and afferent pupillomotor dysfunction following enucleation presented to the Animal Health Trust (AHT), Newmarket, UK, between January 1994 and January 2010 were reviewed. Information recorded included history, signalment, ophthalmic findings, electroretinography (ERG) (2/6) and MRI (3/6) findings and long-term outcome. Pearson’s chi-square tests were used to compare breed proportions (P < 0.05).

Results Six cats aged 1.5 to 11 (median 5.5) years presented with mydriasis and/or visual deficits noted immediately following enucleation. Enucleation involved optic nerve (ON) ligation in all of the four cases for which this information was available. Ophthalmic findings included mydriasis with absent pupillary light reflex (PLR) (4/6), incomplete PLRs (2/6), absence of dazzle reflex (4/6) and absence of menace response (4/6). Funduscopy initially revealed multifocal peripapillary retinal lesions, with subsequent progressive optic nerve head (ONH) and retinal atrophy. ERG recordings revealed normal outer retinal function at 6 and 22 weeks (2/2). On MRI, the optic chiasm (OC) ipsilateral to the enucleation could not be identified and the contralateral OC was atrophied (3/3).

Conclusions The acute afferent ON deficits following enucleation, progressive ONH atrophy, normal outer retinal function and MRI demonstrating OC pathology are consistent with chiasmal injury due to traction on the ON during enucleation. Rostral traction on the globe to facilitate ON ligation is contraindicated in cats.

Key Words: blindness, cat, chiasmal trauma, enucleation

INTRODUCTION

Contralateral optic neuropathy and retinopathy are devastating sequelae to enucleation. Visual and afferent pupillomotor deficits are recognized as potential complications following enucleation of the contralateral eye especially in cats where iatrogenic tractional injury at the level of the optic chiasm (OC) is suspected.1–4 Despite the potential risk of OC tractional injury during feline enucleation, optic nerves (ON) clamping and/or ligation is described by some authors5,6 and it appears that this is still performed in clinical practice.

This retrospective study investigates the etiology and natural history of contralateral optic neuropathy and retinopathy associated with visual and afferent pupillomotor dysfunction following enucleation in six cats.

MATERIALS AND METHODS

The medical records of cats with contralateral visual and afferent pupillomotor dysfunction following enucleation presented to the Unit of Comparative Ophthalmology, Animal Health Trust (AHT), Newmarket, UK, between January 1994 and January 2010 were reviewed. Informa-
tion recorded included age, gender, breed, reason for enucleation, surgical technique used for enucleation, the time following surgery until contralateral ophthalmic signs were noted, ophthalmic findings at the initial and subsequent examinations, and long-term afferent pupillomotor and visual outcome. Follow-up information was obtained where possible by re-examination of patients or completion of a telephone interview with the referring veterinary surgeons or owners.

Complete ophthalmic examination was performed in all cases, including slit-lamp biomicroscopy (Kowa SL 14, Kowa, London, UK), direct ophthalmoscopy (Keeler, Windsor, Berkshire, UK), binocular indirect ophthalmoscopy (Keeler All Pupil, Windsor, Berkshire, UK) and applanation tonometry (Tono-Pen XL®, Reichert, Depew, New York, USA). Fundus photographs were available for all cases, and serial photographs in 3 of 6 cases obtained using either a Kowa RC-2 or Kowa Genesis fundus camera (Kowa Europe, Düsseldorf, Germany).

Results of ancillary testing procedures including ERG (2/6) and MRI (3/6) were also reviewed. Full-field flash ERGs were performed under general anesthesia using a Medelec Synergy N3EP electrodeagnostic unit (Viasys Healthcare, Warwick, UK). Following premedication with a combination of midazolam (Hynnovel®, Roche Products LTD, Welwyn Garden City, Hertfordshire, UK) 0.25 mg/kg, medetomidine (Domitor® Janssen Animal Health, Basingstoke, Hampshire, UK) 10 μg/kg, and buprenorphine (Vetergesic®, Reckitt Benckiser Healthcare Ltd, Hull, UK) 20 μg/kg intramuscularly, anesthesia was induced with intravenous propofol (Rapinovet®, MSD Animal Health, Walton, Milton Keynes, UK) and maintained with a gaseous mixture of oxygen, nitrous oxide and isoflurane (Isoflo®, Abbott Laboratories Ltd, Maidenhead, Berkshire, UK). Following 20 min of dark adaptation, the combined rod – cone response was recorded using a full flash intensity of 30 cd.s/m². Magnetic resonance imaging was performed under general anesthesia in all cats using a 1.5 T MRI unit and a human extremity coil (Signa 1.5T GE Medical Systems, Milwaukee, WI, USA). Images were acquired in all 3 planes and included T2-weighted, pre- and postcontrast (Gadopentetate dimeglumine [Multi- hance, Bracco, High Wycombe, UK] at a dose of 0.1 mmol/kg) T1-weighted fast spin echo (FSE) sequences. Additional thin slice (2 mm slice) images were acquired in the transverse plane. Images of the ON and OC were compared with those of a visually normal cat and a cat in which an uncomplicated enucleation had been performed three years previously (control cat). Both these cats were 15-year-old neutered male DSH cats, and MRI of the head had been performed for investigation of signs unrelated to neuro-ophthalmologic disease.

To identify any breed predisposition, the affected breeds were compared with the total number of cat breeds examined at the AHT during the same time period using the Pearson’s chi-square tests. Similarly, the proportions of cats of brachycephalic and nonbrachycephalic breeds were also compared. Significance was set at $P < 0.05$.

**RESULTS**

Information from the medical records of the 6 cats is summarized in the Table 1. Breeds included DSH cat (5/6) and Turkish Van (1/6). The DSH was not statistically overrepresented when breed proportions were compared with Pearson’s chi-squared test ($P = 0.15$). Similarly, when nonbrachycephalic cats were compared with brachycephalic cats, the nonbrachycephalic cats were not statistically overrepresented. The cats were aged from 1.5 to 11 (median 5.5) years. There was no gender predisposition (three male, three female). All enucleations involved the left eye (6/6). The contralateral eye was reported as normal and visual in all cases (6/6) with no anterior or posterior segment pathology being described prior to surgery. The reason for enucleation was reported to be chronic uveitis (5/6) and chronic keratoconjunctivitis (1/6). In all four cases where the surgical technique used for enucleation could be ascertained, ligation of the ON prior to its sectioning was reported.

The ophthalmic signs reported by the referring veterinarians immediately following enucleation included mydriasis (6/6) and visual deficits (4/6). Ophthalmological findings at the time of presentation to the AHT included complete mydriasis with negligible to absent pupillary light reflexes (PLRs) (4/6), slow and incomplete PLRs (2/6), absence of a dazzle reflex and menace response (4/6). The two patients (cases 3 and 5) that retained a slow and incomplete PLR (with approximately 1/3 pupillary constriction) were the same two cases, which retained a dazzle reflex and menace response. The menace response in these cases could only be elicited from the nasal visual field indicating a temporal visual field loss (temporal hemianopia). Despite the lack of a menace response and dazzle reflex in 4 of 6 cases, only two patients were considered to be completely blind (case 1 and 2). The presence of some residual visual function was based on the ability to fixate and to negotiate a foreign environment. Visual and afferent pupillomotor function at presentation did not alter over follow-up periods of 2 to 252 weeks post-enucleation (6/6).

Ophthalmic examination revealed no anterior segment pathology and normal intraocular pressures in all affected cats. The fundus findings for all cats studied are summarized in Table 1. Fundus examination at 1.5 weeks post-enucleation revealed no abnormalities (case 1). Fundus examination from 2 to 16 weeks post-enucleation revealed multifocal retinal lesions distributed mainly in the peripapillary area and a zone surrounding the tapetal and nontapetal junction (Figs 1 & 2). The fundus changes included circular to linear bullous lesions and inactive hyperpigmented areas in both the tapetal and nontapetal fundus. The bullous lesions were present in all five cases examined between 2
Table 1.Signalment, clinical features, investigations, and follow-up in post-enucleation optic neuropathy and retinopathy in cats.

<table>
<thead>
<tr>
<th>Patient No./Age/ Sex/Breed</th>
<th>Eye/reason for enucleation</th>
<th>Surgical technique</th>
<th>Signs immediately post-enucleation</th>
<th>Signs on referral and follow-up: Time/findings</th>
<th>ERG: Time/findings</th>
<th>MRI: Time/findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/5 y/FN/DSH OS/Chronic uveitis, phthisis bulbi</td>
<td>Unknown</td>
<td>Mydriasis/blindness</td>
<td>1.5 w/Mydriasis, PLR (--), dazzle (--), menace (--), fixation (--), fundus NAD</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>2/11 y/MN/DSH OS/Chronic uveitis</td>
<td>Unknown</td>
<td>Mydriasis/blindness</td>
<td>10 w/Mydriasis, PLR severely ↓, dazzle (--), menace (--), fixation (--), negotiate foreign environment (+), focal peripapillary bullae and pigmentary lesions, ONH atrophy</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>3/1.5 y/FN/DSH OS/Chronic uveitis following penetrating injury</td>
<td>Transconjunctival with ON ligation</td>
<td>Mydriasis</td>
<td>6 w/Mydriasis, PLR severely ↓, dazzle (+) menace (+) (nasal visual field), fixation (+), negotiate foreign environment (+), focal peripapillary bullae (orange central areas) and pigmentary lesions, pigment dispersion in nontapetum fundus, ONH and retinal degeneration</td>
<td>108 w/OC – Asymmetric OS – ON not visualized OD – ON mild atrophy with increased CSF</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4/2 y/MN/DSH OS/Chronic keratoconjunctivitis</td>
<td>Transpalpebral with ON ligation</td>
<td>Mydriasis</td>
<td>6 w/Mydriasis, PLR severely ↓, dazzle (--), menace (--), fixation (+), negotiate foreign environment (+), focal peripapillary bullae (orange central areas)</td>
<td>24 w/OC – Asymmetric OS – ON not visualized OD – ON mild atrophy with increased CSF</td>
<td>6 w/Normal</td>
<td>22 w/Normal</td>
</tr>
<tr>
<td>5/5 y/FN/DSH OS/Chronic uveitis</td>
<td>Transpalpebral with ON ligation</td>
<td>Mydriasis/visual deficits</td>
<td>16 w/Mydriasis, PLR severely ↓, dazzle (+), menace (+) (nasal visual field), fixation (+), negotiate foreign environment (+), focal peripapillary bullae (orange central areas), ONH atrophy</td>
<td>24 w/OC – Asymmetric OS – ON not visualized OD – ON mild atrophy with increased CSF</td>
<td>–</td>
<td>–</td>
</tr>
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</table>
and 16 weeks post-enucleation. In four of the five cases in which bullous lesions were evident, the bullous lesions were centered on a slightly elevated focal red-orange core. This appearance was transient with the red-orange core become rapidly hyperpigmented in cases monitored over several days. From 20 weeks, progressive signs of optic nerve head (ONH) atrophy and retinal degeneration were evident (Fig. 3). Advanced retinal degeneration was seen in one case followed for 252 weeks (case 3).

Full-field flash ERG recordings revealed no evidence of significant outer retinal dysfunction at 6 (case 4 and 6) and 22 weeks (case 4).

On MRI, the OC of the control cat (Fig. 4a) was similar in size and appearance to that of the normal cat (Fig. 4b). On MRI of the affected cats (3/3), the OC was reduced in size compared with the control cat and the normal cat (Fig. 4). In all three affected cats, the left (ipsilateral) side of the OC could not be identified and the right (contralateral) side was atrophied (asymmetric atrophy). In two affected cats, the right side of the chiasm could not be identified on 3 mm slices but was visible on the thin slice (2 mm) images.

On MRI in the control cat (Fig. 5a), the ON ipsilateral to the enucleation (right eye) was clearly visible but reduced in size and surrounded by a subtle increase in CSF volume when compared with the ON of a normal cat (Fig. 5b). The ON contralateral to the enucleation in the control cat was normal in appearance (Fig. 5a). On MRI of the affected cats, the ON was atrophied on the side ipsilateral to the enucleation in one case and could not be identified in two. In all three affected cats, the ON contralateral to the enucleation was mildly atrophied and the volume of CSF around the ON was subjectively increased (Fig. 5c). In all affected cats, changes were most clearly seen on T2-weighted images in the transverse and paramedian planes obtained with 2 mm slices. In all affected cats, the brain other than OC was normal with no abnormal enhancement of ONs or orbit contralateral to the enucleation following intravenous gadolinium contrast administration. MRI examinations were performed more than 3 months after enucleation in all three affected cats.

**DISCUSSION**

The findings of this study which included the acute onset of afferent ON deficits immediately following enucleation of the contralateral eye, progressive ON atrophy, normal ERG recordings and MRI demonstrating OC pathology are consistent with OC tractional injury at the time of surgery. Although the risk of OC tractional injury has been described,1–4 ON clamping and ligation during feline enucleation is still performed in practice. For all affected cases in this study where information regarding the surgical technique was available (4/4), the ON was ligated prior to sectioning.
The increased risk of ON damage following enucleation in the cat is attributed to several anatomical features. The mammalian ON has a mild sigmoid flexure, presumably to accommodate ocular motility, and consequently, a degree of physiological globe protrusion can occur without ON traction. The feline ON lacks the degree of sigmoid flexure present in dogs and therefore is more prone to tractional injury when the globe is rostrally displaced.\(^3\) The feline orbital space is also relatively small, with the orbit being only slightly bigger than the globe.\(^7\) This restricts access to the region posterior to the globe increasing the risk of ON traction during attempts to surgically expose the ON. The authors’ postulated that cats with deeper orbits would be at greater risk of ON tractional injury than brachycephalic cats with shallow orbits in which surgical access to the region posterior to the globe was more easily attained. Although there appeared to be a trend to support this theory with no brachycephalic cats being affected, the DSH (i.e. non-brachycephalic) was not statistically overrepresented. The inability to detect a statistically significant association is not surprising given the very small study population; however, a larger, multicenter study might conceivably have the power to do so.

The pathophysiology of OC trauma in humans has been extensively studied.\(^8\) Such injuries are usually indirect as direct trauma in this region is usually fatal.\(^8\) Indirect injuries are usually caused by a blunt and violent impact in the frontal or more rarely in the parietal region.\(^8\) The association between forehead trauma and visual deficits was known in the time of Hippocrates and described in ‘De Morbis Vulgaribus’ (circa 400 B.C). The majority of these injuries in the modern age follow severe head trauma associated with motor vehicle accidents.\(^8\) Visual deficits following milder forms of trauma may also occur such as that described by Praun in 1899 in which unilateral blindness associated with ON atrophy followed a ‘blow to the eyebrow with a potato’\(^8\).

**Figure 1.** Fundus photographs of case 2 (a and b), 3 (c and d) and 4 (e and f), 6 weeks postenucleation. Multifocal peripapillary hyporeflective areas and bullous changes were identified from 2 to 6 weeks post-enucleation. These lesions were transient with active lesions quickly becoming focally hyperpigmented. Picture (e): the red-orange central region within the focal bullous lesion was a typical feature of early lesions.
Various pathophysiological mechanisms for the OC injury following blunt trauma have been proposed including bony fractures in the region of the chiasm, mechanical stretching causing tears in the crossing fiber bundles, and disruption of OC blood supply by shearing, thrombosis and spasm of small pial vessels. Gross pathology of the OC following blunt trauma in people is commonly associated with splitting of the OC in the mid-sagittal plane. This has been demonstrated with MRI, post-mortem examination and experimental studies. The experiments of Østerberg in 1938 approximate the possible in vivo mechanical effect resulting from excessive ON traction during a feline enucleation. In these experiments, the OCs of 5 human cadavers were mechanically stretched with varying degrees of force and suddenness of traction. This produced both macro and microscopic tears in the median plane of the OC. In cats in which excessive traction is placed on the ON during enucleation, the mechanism of chiasmal damage is likely to reflect a combination of mechanical stretching and disruption of the chiasmal blood supply.

The clinical consequences of OC pathology are influenced by the complex anatomy of the region. The percentage of ON fibers that decussate at the mammalian OC is related to binocularity; therefore, how frontal the eyes are placed. The percentage of decussation in a cat is reported to be between 65% and 70%. Once decussation of the nerve fibers has occurred, they form the optic tract.
which contains crossed and uncrossed fibers that will synapse in the lateral geniculate body, rostral colliculus and the pretectal nucleus. The uncrossed fibers remain on the lateral (temporal) aspect of the OC. This explains the preferential sparing of nondecussating temporal fibers with pathology affecting the OC in the median plane. Such preferential OC damage in the median plane is a rare clinical entity in humans, which may follow blunt frontal head trauma and subsequent acute onset bitemporal hemianopsia (traumatic chiasmal syndrome). The reason for this is illustrated in the stereogram (Fig. 6); the spared uncrossed temporal OC fibers are derived from the temporal hemiretina. The ON fibers derived from the lower nasal retinal quadrant may be more vulnerable due to the presence of an anterior genu in which these fibers loop forward into the contralateral ON. The existence of this anterior genu has not been described in cats. Although the anatomical existence of the anterior genu in humans has been questioned, its clinical significance with visual field deficits consistent with the loss of afferent input from the lower nasal retinal quadrant remains valid. The temporal hemianopsia seen in cases 3 and 5 indicates sparing of the nondecussating lateral fibers at the OC and is consistent with chiasmal damage in the median plane.

The progressive ONH atrophy and retinal degeneration evident in all cases are presumed to reflect the retrograde ON degeneration following damage to the OC. The ON is formed by axons of the retinal ganglion cells (RGC), the cell bodies of which form the ganglion cell layer (GCL) in the inner retina. The RGC axons form fibers, which converge at the ONH where they are separated into nerve fiber fascicles and form the ON. Numerous experimental studies have evaluated the pathological changes present in the mammalian ON and retina following ON injury. Following sectioning of the ON, both anterograde (away from the RGC nuclei) and retrograde (toward...
the RGC nuclei) axonal degeneration result.\textsuperscript{16,29} The anterograde degeneration occurs simultaneously along the ON (Wallerian degeneration) to the level of the lateral geniculate body and occasionally neurons farther along the central visual pathways also degenerate (transneuronal degeneration).\textsuperscript{16} The retrograde degeneration of ON axons is described as being similar to that of anterograde degeneration to the first node of Ranvier although eventual degeneration of the RGC body may result.\textsuperscript{16} The loss of RGCs following ON transection involves both apoptotic and nonapoptotic mechanisms, and the rate of retrograde ON degeneration varies with the type of RGC population.\textsuperscript{22,25,26,28}

The uniformity in the appearance and distribution of the acute retinal lesions in all five cases examined between 2 and 16 weeks post-enucleation suggested that a similar pathological process was occurring in all cases and that this was temporally related to the presumed iatrogenic trauma to the OC at the time of enucleation. The appearance of the acute retinal pathology was consistent with focal retinal inflammation, which it was postulated could represent a response to focal areas of RGC death and the subsequent microglial responses in the inner retina. The retinal pigment epithelial changes indicated stimulation of the retinal pigment epithelium (RPE) and/or choroidal involvement. This suggests that the pathology was not

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limited to the inner retina. The suspected outer retina pathology in the cases studied may seem incongruent with experimental studies of ON transection in cats, in which pathology is largely limited to the inner retinal layers. The differences between the retinal pathology evident in the experimental studies vs. the clinical cases may reflect the difference in the insult to the ON: direct ON tractional injury in the clinical case in contrast to sharp ON transection in the experimental cases.

Another possible explanation for the retinal lesions was that of alterations in blood flow to the globe due to vascular lesions associated with OC trauma. This does not seem to be supported by experimental studies in which ON transection in cats was not associated with alterations in the ipsilateral retinal or ONH vasculature. The feline ophthalmic artery is innervated by nerve fibers from the trigeminal (TRG) and superior cervical ganglia (SCG). Anatomically, the nerve fibers from the TRG and SCG are not associated with the OC, and as such, functional changes in the feline ophthalmic artery due to interference with its innervations are unlikely following OC injury.

Although potential causal links between OC trauma and subsequent fundus pathology may be postulated, the pathogenesis of the fundi lesions identified in this study remains undetermined. In five of the six cats, chronic unilateral uveitis was the reason for enucleation, and therefore, the possibility that an underlying disease was responsible for the fundus changes in the contralateral eye needs to be considered. Both the acute retinal lesions and the pigmentary changes indicating RPE and/or choroidal involvement could be consistent with chorioretinitis lesions. This explanation for the fundus pathology seems unlikely given the uniformity in the timing, appearance and distribution of the acute retinal lesions. Of the five cats with chronic uveitis, there were no reports of pathology affecting either the anterior or posterior segment of the contralateral eye prior to surgery. In case 4, there was no prior history of uveitis, although a typical progression of fundi pathology was recorded at 6, 8 and 24 weeks post-enucleation (Figs 1–3). Furthermore, in two of the five cats with chronic uveitis, the disease had followed a penetrating injury, and as such, the contralateral eye should not have been at a greater risk of uveitic disease. The possibility that medication prescribed to these cats prior to enucleation could have been associated with some adverse toxic effects was also considered. In case 4, the potentially retinotoxic drug enrofloxacin was prescribed prior to the enucleation. The retinopathy induced by enrofloxacin in cats is associated with diffuse and extensive outer retinal disease and loss of recordable full-field flash ERG responses. In this case, enrofloxacin was prescribed in accordance with manufacturer’s guidelines reducing the likelihood of an adverse toxic reaction; furthermore, the full-field ERG responses were normal in this case.

Full-field flash ERG recordings revealed no evidence of significant outer retinal dysfunction in two cases at 6 and 22 weeks after contralateral enucleation. The amplitudes and latencies of ERG a and b waves were not consistent with outer retinal dysfunction, or at least a degree of outer retinal dysfunction is sufficient, alone, to account for severe visual compromise/blindness identified in these subjects. Full-field flash ERG remains normal in cats following ON transection in both the acute and chronic stages where loss of RGCs is present. This is explained by the generation of the full-field flash ERG in the outer retina whilst the pathology following ON transection is initially limited to the inner retina.

Specialized electrodiagnostic techniques including the pattern ERG (PERG) and visual evoked potentials (VEPs) and advanced ocular imaging modalities such as optical coherence tomography (OCT), which are at present largely restricted to the research setting in veterinary medicine, would greatly enhance our understanding of the pathology present in such clinical cases. The PERG and VEPs could have utility in evaluating the extent and location of pathology in clinical cases in which ON and inner retinal pathology are suspected. Electrophysiological studies have shown that the PERG in the cat is strongly attenuated and eventually disappears following unilateral...
ON transaction and that this is strongly correlated with the ganglion cells loss in the inner retina.\textsuperscript{33,34} The loss of the PERG in these experiments occurs despite the maintenance of a normal full-field flash ERG. The VEP is a cortical response to a visual stimulus and such allows examination of the integrity of the entire visual pathway from the retina to the visual cortex. In the clinical cases studied herein, a reduced or extinguished VEP would be expected following ON pathology. The clinical utility of VEP studies in the cat\textsuperscript{35–37} and the effects of experimental ON injury on the VEP recordings\textsuperscript{38,39} have been described. Newer imaging modalities such OCT have the potential to provide micron resolution cross-sectional images of the retina in vivo.\textsuperscript{40} The utility of OCT for imaging the feline retina has been demonstrated\textsuperscript{41} and in the future may help define the intraretinal pathology in cases such as those described herein.

The MRI findings in traumatic chiasmal lesions have been reported in humans\textsuperscript{13,14,17,42,43} but to the authors’ knowledge not in the veterinary literature. In humans, high-resolution (1.5 T magnet or greater) MRI with gadolinium contrast enhancement is considered the best imaging modality for lesions involving the OC,\textsuperscript{44} but in clinical practice, computer tomography remains the imaging modality of choice following acute head trauma with post-traumatic blindness, due to its increased sensitivity at detecting optic canal fractures.\textsuperscript{15} The ON of the control cat in which enucleation was performed 3 years prior to MRI showed a slight subjective reduction in the size of the ON ipsilateral to the enucleation and a subjective increase in the volume of CSF surrounding the remaining nerve. These reductions are consistent with the anterograde loss of ON fibers associated with unilateral ON sectioning. In all three cats in which MRI was performed, the period between the enucleation procedure and the MRI examination was more than three months. Therefore, the changes of complete loss of tissue within the ON and OC ipsilateral to the enucleation and asymmetric atrophy of the OC and the partial atrophy of the ON on the contralateral side represent chronic changes. Following routine enucleation with sectioning of the ON just posterior to the globe, some remnant of the distal ON should remain as was clearly visible in the control cat. Complete absence suggests ON pathology at or close to the level of the OC, which is consistent with the proposed traction injury in these cases. Atrophy of the chiasm may be overlooked unless thin (2 mm) slice images are acquired. Gadolinium contrast enhancement was used in the MRI studies of these cases, but no abnormal contrast enhancement was noted. This is likely to reflect the time between the enucleation and MRI during which any microvascular or inflammatory changes associated with the ON trauma are presumed to have subsided. The use of gadolinium contrast may increase the sensitivity for detecting microvascular or inflammatory disease of the OC in the first few weeks following surgery. It may be of particular benefit in cases with afferent ON defects but without gross disruption of the OC seen in this study.

No further change in visual or afferent pupillomotor function occurred in the cases studied over follow-up periods of 2 to 252 weeks post-enucleation. Treatment was limited to one cat which received a relatively low dose of prednisolone; 1 mg/kg/day \textit{per os} for 10 days.

High-dose corticosteroids (methylprednisolone acetate; MPA) have been used to treat acute traumatic optic neuropathy in humans despite a lack of evidence for its efficacy.\textsuperscript{45} More recent experimental evidence suggests that high-dose MPA may be harmful to the ON in traumatic\textsuperscript{46} and immune-mediated optic neuritis models.\textsuperscript{47} Based on current clinical and experimental evidence, the use of high-dose MPA is currently not recommended for human traumatic optic neuropathy.\textsuperscript{45} No cat in this series received high-dose corticosteroid therapy.

Interestingly, the authors could find no reports of contralateral optic neuropathy and retinopathy following scheduled enucleation in people. The closest clinical cases parallel to the cases described herein are the cases of human auto-enucleation in which excessive traction is often placed on the ipsilateral ON and therefore the OC. In a review of human autoenucleation patients, temporal hemianopia was found in the remaining eye in 7 of 31 cases.\textsuperscript{48} MRI studies on two human patients revealed absence of the ON and OC asymmetry\textsuperscript{43} and ipsilateral absence of the OC.\textsuperscript{42}

Given that visual field losses such as temporal hemianopia are easily overlooked in veterinary patients, the incidence of contralateral optic neuropathy and retinopathy following enucleation may be underestimated. Great care is needed during enucleation to avoid traction on the ipsilateral ON. The only advantage of ON clamping and/or ligation before sectioning the ON is improved hemostasis. In humans, avoidance of ON clamping before ON sectioning has been recommended due the difficulty in exposing the region and the fact that direct tamponade is usually adequate to control any associated ON hemorrhage.\textsuperscript{49} In the authors’ experience this is similarly true for domestic animals. Hemorrhage associated with the section of the feline ON and associated vasculature during enucleation is typically negligible. Allgoewer and others in 2006 reviewed 215 patients (including 79 cats) in which enucleation was performed without clamping and/or ligation of the ON; in no patient was hemorrhage reported that could not be controlled by intra-operative tamponade.\textsuperscript{50}

CONCLUSIONS

Critical evaluation of textbooks is needed when surgical procedures are being reviewed. Great care and good dissection are required when enucleating eyes. In the feline species, the lack of sigmoid structure of the ON and relatively small orbit makes exposure of the ON during
enucleation difficult. Rostral traction on the globe to increase surgical exposure of the ON for clamping and/or ligation is unnecessary and given the risk of iatrogenic blindness contraindicated in cats.

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