APHAKIC PHACOEMULSIFICATION AND AUTOMATED ANTERIOR VITRECTOMY, AND POSTRETURN MONITORING OF A REHABILITATED HARBOR SEAL (PHOCA VITULINA RICHARDSI) PUP


Abstract: A female harbor seal pup rescued along the coast of San Diego on 13 June 2012 was diagnosed with bilateral mature cataracts, apparently congenital, in association with vitreal herniation in the anterior chamber of each eye. The cataracts were surgically removed on 1 August 2012 with single-port aphakic phacoemulsification and automated anterior vitrectomy. Postoperative monitoring during the next several weeks indicated that vision had been functionally repaired and that she could visually orient to and capture live fish in three different environments and in the presence of other animals. Consequently, we equipped the seal with a satellite-linked radio transmitter and returned her to the Pacific Ocean on 21 November 2012, and then monitored her movements until radio contact ended on 2 March 2013. She remained along the San Diego coast from 21 November until 5 December 2012 when she relocated to the Coronado Islands and remained there until 26 December. She then traveled directly to San Clemente Island and remained foraging in the near-shore kelp beds there through 2 March 2013, when radio contact ended. To our knowledge, this is the first published report of cataract treatment in a marine mammal using high-frequency ultrasound to emulsify the lenses followed by suction removal of the emulsified microfragments (i.e., phacoemulsification). Moreover, the rapid postoperative recovery of the seal and its quick acclimation, orientation, navigation, and foraging in marine habitats after return to the Pacific Ocean indicates that these surgical procedures can be safe and effective treatments for cataracts in seals, with substantially reduced postsurgical complications relative to other types of lens fragmentation and removal procedures.

Key words: Anterior vitrectomy, aphakic phacoemulsification, cataract surgery, harbor seal, Phoca vitulina richardsi, postrehabilitation tracking.

BRIEF COMMUNICATION

Relatively large numbers of marine mammals strand in poor condition on beaches along the Pacific Coast of North America each year and are rescued and rehabilitated by a number of privately operated animal care facilities and aquaria. The U.S. National Marine Fisheries Service (NOAA Fisheries), which is delegated with executing the U.S. Marine Mammal Protection Act,1 compels marine mammal rehabilitation facilities to return, with rare exception (e.g., chronic neurological pathology, previous exposure to particular infectious pathogens), all stranded and rescued animals to ocean waters promptly, following brief recuperation, medical treatment, and rehabilitation.

A recently weaned female harbor seal pup (Order Carnivora; Family Phocidae), in poor body condition, was rescued by SeaWorld San Diego animal care staff from the outer coast of Point Loma, San Diego, California on 13 June 2012. Complete blood count and serum chemistry showed a mild anemia and hypoproteinemia, consistent with malnourishment, so she was subsequently hydrated, hand fed, and provided nutritional supplements during the next several months of recuperation.

The seal was also diagnosed with bilateral (mature) cataracts, suspected to be congenital. Neuroophthalmic examination revealed a complete palpebral reflex OU (oculus uterque = each eye). Dazzle reflexes were present bilaterally, as were sluggish and incomplete pupillary light reflexes (PLRs), though menace responses were bilaterally absent. Intraocular pressures (IOPs) approximated 16 mm Hg OD and 14 mm Hg OS (Tonovet, Acrivet, http://www.acrivet.edu/). Examination by slit-lamp biomicroscopy indicated a small amount of degenerate vitreous material extending...
through the pupil into both anterior chambers and mature cataractous lenses, which precluded fundoscopic evaluation. Lenticular instability was further indicated by a mild degree of phacodendrosis OU.

As the seal’s body condition and health improved it was decided to remove her cataracts surgically. Presurgical treatment consisted of Fred-G (Allergan Inc., Irvine, California, USA, http://www.allergan.com/home) OU four times daily and oral dexamethasone (BoehringerIngelheim, Roxane Laboratories, Inc., Columbus, Ohio, USA, https://www.roxane.com/; 0.1 mg/kg) once daily. On 1 August 2012 the seal was premedicated with an antimuscarinic agent (0.02 mg/kg atropine) 20 min prior to induction of anesthesia. The seal was then anesthetized with propofol (Propoflo™, Abbott Laboratories, North Chicago, Illinois, USA, http://www.abbott.com/; 4 mg/kg IV), and then maintained with sevoflurane (Sevoflurain™, Butler Schein Animal Health, Dublin, Ohio, USA, https://www.henryscheinvet.com/) in air via a guarded endotracheal tube. The general anesthesia provided the necessary analgesics. To circumvent dive apnea and hypercapnia the seal was manually ventilated throughout the procedure. The entidal CO₂ was maintained between 40% and 50% throughout the procedure, and neither vagal reflex nor apnea were observed. Ocular B-mode ultrasonography and electroretinography (Retinographics Inc., Norwalk, Connecticut, USA, http://www.retinographics.com/) were performed, and generated readings were considered to be within normal limits.

Neuromuscular blockade was performed with the use of Atracurium 0.1 mg/kg IV (Atracurium, SAGENT Pharmaceuticals, Schaumburg, Illinois, USA, http://www.sagentpharma.com/). Following diagnostic testing, the seal was placed in dorsal recumbency. After fornix preparation with the use of a dilute betadine solution and aseptic draping, a 2.7-mm angled paracentesis knife (Surgical Specialties Corp, Angiotech, Pennsylvania, USA, http://www.surgicalspecialties.com/) was used to make a single perilimbal corneal incision. The pupil was pharmacologically dilated with the use of a dilute solution of 1:1000 epinephrine, and the anterior chamber maintained with Na-hyaluronate OVD (CARA Inc., Rancho Cucamonga, California, USA, http://www.caraskincare.ca/). The cataracts were then removed by single-port phacoemulsification (i.e., emulsification of the lenses with ultrasound) and subsequent limited anterior automated vitrectomy.

Anti-inflammatory (dexamethasone) and miotic (carbachol) agents were instilled intra-camerally and an antimicrobial agent (chloramphenicol) was injected subconjunctivally prior to recovery. The entire procedure lasted about 1 hr. The seal was monitored closely by attending veterinarians for 6 hr directly after the end of the surgery.

The seal was kept out of the water postoperatively for 1 wk to allow the incision to heal. Postoperative medications included oral anti-inflammatory doses of dexamethasone (0.1 mg/kg) starting at once daily for 14 days and then a tapered dose (0.05 mg/kg) once daily for 4 days, and oral antimicrobial doses of doxycycline (10 mg/kg; West-ward Pharmaceutical Corp., Eatontown, New Jersey, USA, http://www.west-ward.com/) twice daily for 9 days, and then replaced with enrofloxacin (3 mg/kg; Baytril®, Bayer Animal Healthcare LLC, Shawnee Mission, Kansas, USA, http://animalhealth.bayer.com/ah/index.html) twice daily. Topical ophthalmic medications (prednisone acetate 1%/gentamicin 0.3%, Allergan, Irvine, California, USA, http://www.allergan.com/home) were administered at a tapering frequency for 24 days after the surgery to minimize inflammation and pain. The surgical sites were monitored daily by the attending veterinarians until the seal was returned to the ocean on 21 November 2012. Those observations specifically focused on any signs of postsurgical ocular pain (e.g., blepharospasm) and conditions known to be potentially painful (e.g., uveitis). No signs of either were observed. Postoperative recovery and healing were uneventful and there were no signs of corneal opacification or any other postoperative complication or abnormality.

During the seal’s postsurgical recovery she was first fed thawed fish by hand for several weeks. Live fish was then introduced to three different pools where she was recuperating, including those where other rehabilitating seals and sea lions were being kept, to determine the appropriateness of returning her to the Pacific Ocean. She quickly oriented to those fish visually and captured them relatively easily. She also detected animal care staff and visitors visually and tracked them quickly and routinely. Consequently, plans were developed to return the seal to ocean waters and to then monitor her behavior for several months.

To monitor the seal’s free-ranging movements, we attached (with quick-setting epoxy) a satellite-linked radio transmitter to the hair on the top of the seal’s head on 20 November 2012 and monitored her behavior at SeaWorld for the next
The transmitter weighed \(<100\) g in air, was near neutral density in seawater, and measured 72 mm \(\times\) 54 mm \(\times\) 25 mm. The seal was transported by boat to kelp beds along the coast of San Diego (32.699°N, 117.274°W) and released at 0930 hr PST on 21 November 2012 (Fig. 1). She began diving immediately and appeared to be able to orient visually in the nearshore kelp beds while we observed her for about 30 min. We then monitored her movements through the Argos Data Collection and Location Service from just after her return until radio signals ended on 2 March 2013, and plotted her daily whereabouts using locations of LQ > 0.14. She remained along the San Diego coastline from 21 November through 5 December 2012, and then moved directly to the Coronado Islands later that day. Transmitted summary data on diving patterns indicated that she foraged in shallow kelp beds near the Coronado Islands and periodically hauled out on Middle Coronado Island through 25 December 2012, and then made a quick trip to San Diego and back to the Coronado Islands within 24 hr. She then traveled directly from the Coronado Islands to San Clemente Island on 26 and 27 December (Fig. 2). She remained along the west side of San Clemente Island, and then briefly on the northern tip of the island, through 2 March 2013, when radio contact ended. Though she had been diving regularly until then and the battery power appeared to still be adequate, we cannot say why radio transmissions ended. The transmitter might have simply failed, it might have detached, or perhaps the seal was killed by a resident or transient predator (e.g., blue shark, white shark, killer whale).

Figure 1. A rehabilitated harbor seal with a satellite-linked radio transmitter attached just after her return to waters off San Diego on 21 November 2012 following cataract removal surgery.

Figure 2. Locations and movements of a rehabilitated harbor seal, from 21 November 2012 through 2 March 2013, showing daily locations (dots) and movements (lines) while off San Diego (21 November–5 December 2012), at the Coronado Islands (5 November–25 December 2012), and at San Clemente Island (27 December 2012–2 March 2013).
There is a robust colony of harbor seals that lives along the coast of San Diego, and they haul out primarily at Children's Cove in La Jolla, where small numbers of pups are born each year in March and April. There is also a small harbor seal haulout site near where the debilitated harbor seal pup was found near Pt. Loma, and there are very small colonies of harbor seals at the Coronado Islands and at San Clemente Island. Harbor seals in Southern California forage principally on epibenthic prey in and near kelp beds. The seal’s use of those habitats along the coast of San Diego and then direct relocation to and use of similar habitats at the Coronado Islands and then at more remote San Clemente Island suggests that she quickly and effectively located appropriate habitats to forage in and integrated relatively well into those communities during the 3 mo that we tracked her, despite being aphakic. To the extent that NOAA Fisheries compels marine mammal rescue facilities and aquaria to return virtually all rescued marine mammals to ocean waters after brief recuperation, we think that it is important to monitor their postreturn behaviors to assess their survival and well-being to help better judge whether return is always the most appropriate option.

Several methods to remove lenses from eyes are currently used to treat cataracts in humans and various species of wildlife and domestic animals. Removal of the entire lens (i.e., lensectomy) requires larger and often multiple incisions, potential damage to the anterior and posterior capsules, and postsurgical complications in healing and recuperation. Cutting or chopping the lens into several pieces (i.e., phacofragmentation) with small blades, nylon loops, and other devices and then physical removal, sometimes assisted with suction, of those few pieces allows smaller incisions to be used and fewer postsurgical complications than attempts to remove the entire lens. The use of that manual fragmentation process can be limited if the lens nucleus is too hard to be cut into pieces easily. Use of ultrasound to emulsify the lens of an eye with a high-frequency ultrasound probe and then suction removal with the same probe of the emulsified microfragment remains (i.e., phacoemulsification) differs fundamentally from the physical cutting of the lens into two to several fragments. This procedure also requires a much smaller surgical incision, and results in fewer postoperation complications and quicker recovery.

There are two published accounts of cataract removals in marine mammals. Dutton reported on the treatment of a cataract in a New Zealand fur seal by direct extraction (i.e., not phacoemulsification) of the entire lens. Barnes and Smith reported on the removal of bilateral cataracts from a New Zealand fur seal. The procedure used by Barnes and Smith apparently involved attempts to cut the lenses into several pieces (i.e., phacofragmentation) before extracting the lens fragments directly. The authors were unable to reduce the lens nucleus in one eye into smaller pieces and had to extract it as a single piece, whereas the lens in the other eye was evidently broken down into a few smaller pieces, which were then extracted directly. There were a number of postsurgical complications and trauma and delayed healing of the incisions. In each case, the animal remained in captive care permanently after the surgery.

In an unpublished abstract Colitz briefly summarized the removal of lenses of 40 individuals of four species of Otariid carnivores (fur seals and sea lions, but virtually all of them were California sea lions) and seven individuals of two species of Phocid carnivores (six harbor seals and one northern elephant seal) from 2002 to 2011. In all but perhaps one of those individuals, the lenses were evidently physically fragmented (i.e., not phacoemulsification) followed by direct removal of the two to several residual fragments, and there were a number of postoperative complications and pathologies. The removal of the lens(es) of one phocid individual (species unspecified), perhaps by phacoemulsification, was mentioned, but no details of the procedure were described. One (a young elephant seal) of the 47 individuals was evidently released into the ocean following recovery from surgery with undetermined result.

To our knowledge, this report is the first published account of the treatment of cataracts in a marine mammal by phacoemulsification (i.e., using high-frequency ultrasound to emulsify the lenses into microfragments followed by suction evacuation of the emulsified remains). Moreover, incorporating the additional procedure of anterior or vitrectomy can help with the phacoemulsification surgical procedure and also enhance postoperative rehabilitation. The rapid postoperative recovery of the seal and its quick acclimation, orientation, navigation, and foraging in marine habitats after return to the Pacific Ocean indicates that these surgical procedures can be safe and effective treatments for cataracts in young harbor seals at least, with substantially reduced postsurgical complications relative to other types of lens fragmentation and removal.
procedures. The results indicate that the permanent removal of eye lenses (i.e., aphakic condition) does not necessarily preclude returning a seal to its ocean habitats. We recommend monitoring of all marine mammals that undergo rehabilitation and surgical procedures after being returned to ocean habitats to help evaluate their re-integration.

LITERATURE CITED

1. 16 U.S.C. §1361 et. seq.


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