SURGICAL TREATMENT OF OSTEOARTHRITIS IN HARBOR SEALS (*PHOCA VITULINA*)

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Abstract: In 2012, 543 harbor seals (*Phoca vitulina*) and 124 grey seals (*Halichoerus grypus*) were admitted to the Seal Rehabilitation and Research Centre in Pieterburen, The Netherlands. In 19 seals (3%), signs of infection in a hind flipper were observed. Initial treatment consisting of antibiotics and anti-inflammatory drugs resolved the symptoms in 15 animals. In four harbor seals, estimated to be 3 to 4 mo old, a necrotizing infection developed that resulted in osteoarthritis of the tarsus or tibiotarsal joint or both. Bacterial culture revealed the presence of polymicrobial infection in three of the four animals. Treatment consisted of amputation of the hind flipper under general anesthesia combined with tumescent anesthesia in the operation field. Amputations were done at the diaphysis of the tibia and fibula. After resecting these bones, the flipper was discarded, leaving a good muscle-skin cuff to cover the edges of the bones and close the skin without tension. The estimated blood loss varied between <50 to 150 ml. Healing was uneventful, and both antibiotics and analgesics were gradually reduced according to the individual response. The seals did not show any functional impairment 1 mo postoperatively. After release to the sea, scrutinous revision of all radiographs showed signs of osteomyelitis in at least one animal in the proximal part of the tibia, also present preoperatively. It is concluded that tumescent anesthesia in seals may reduce perioperative blood loss and that a lower leg amputation is a surgically easy and clean approach for the treatment of osteoarthritis of the hind flipper of seals, giving good functional results (diving, catching fish, exiting a pool, and moving on land).

Key words: Amputation, common seal, harbor seal, osteoarthritis, *Phoca vitulina*, Wadden Sea.

INTRODUCTION

The coast of The Netherlands, Germany, and Denmark bordering the southeastern part of the North Sea is characterized by the presence of a chain of 45 mainly short barrier islands, half of them inhabited, surrounded by tidal mud flats and tidal creeks. This area, called Wadden Sea (in Dutch *Waddenzee*), with a surface of 10,000 km^2, accommodates a rich flora and fauna with seagrass meadows, shells, and 12 million birds a year. The Wadden Sea became one of the present 46 Marine World Heritage sites in 2009.

The two species of seals indigenous to Dutch waters are harbor seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*). The number of harbor seals in this area declined significantly prior to the 1970s due to centuries of hunting and pollution.[6,11,16] In 1977, only 430 harbor seals were

observed in the Wadden Sea.[17] In 1988, phocine distemper virus caused mass mortality among harbor seals.[10] A second epidemic occurred in 2002.[4,13] Remains of grey seals have been found at archeologic sites along the Wadden Sea coast.[1] Grey seals disappeared from the Wadden Sea, presumably due to hunting, but repopulation took place during the last three decades.[12]

The Seal Rehabilitation and Research Centre (SRRC) in Pieterburen, The Netherlands, has rehabilitated seals stranded on the Dutch coast since 1971. The SRRC stranding network rescues beached seals and also collects carcasses of stranded marine mammals. This network covers the entire coastline of The Netherlands, with the exception of the island of Texel, which is covered by another rehabilitation center, Ecomare. The Netherlands has an accessible coastline and therefore a high detection rate for stranded marine mammals.

In the past, seals with a severe infection (osteoarthritis in the tarsus or more proximally) in a hind flipper either died during rehabilitation due to sepsis or were treated with an amputation, which in half of the cases resulted in death on the operation table, or shortly thereafter due, to what was considered to be anesthesia problems or the result of surgical failure (postoperative bleeding). Healing of such an infection with only antibacte-

rial treatment has never been observed in the SRRC.

CASE SERIES

Animals

During 2012, 667 seals were admitted for rehabilitation to the SRRC: 543 harbor seals and 124 grey seals, mainly weakened and ill young animals (whereas in 2011, 836, in 2010, 594, and in 2009, 468). In that year, 19 young seals (3 male and 2 female grey seals and 11 male and 3 female harbor seals) presented with an infection of a hind flipper. Bacterial infections being common in seals, initial treatment routinely consisted of administration of antibiotics, such as amoxicillin-clavulanic acid (50, 250, or 500 mg tablets, Le Vet B.V., 3421GW Oudewater, The Netherlands; 20 mg/kg p.o. b.i.d. for 7 to 10 days), clindamycin (200 mg tablets, AST Beheer B.V., 3421GW Oudewater, The Netherlands; 10 mg/kg p.o. b.i.d. for 14 days), and an anti-inflammatory drug, such as carprofen (AST Beheer B.V; 2 mg/kg p.o. b.i.d. for 10 days). Fifteen cases, with an apparently mild infection, healed with this treatment, while four animals developed a necrotizing infection, resulting in osteoarthritis in the tarsus or tibiotarsal joint or both. These four animals, identified in order of admission as 12-430, 12-471, 12-473, and 12-486, were all harbor seals with an estimated age of 3 to 4 mo. They presented with severe inflammation of one hind flipper, pain on palpation of the affected limb, lethargy, dehydration, and poor body condition. The affected flipper (the right hind flipper in case 12-486 and the left hind flipper in the other three cases) did not show the presence of any wound and, in one case (12-430), a small scar not related to the area of swelling. In three of them, spontaneous drainage developed due to the pressure of inflammation and necrosis of soft tissues, and in one, an incision was made in the medial side of the tarsal joint, revealing edematous tissue.

After the diagnosis of an infection in the region of the tarsus had been established, radiographs of that region were taken in the four animals. In the animal 12-430, a radiograph taken shortly after admission did not show abnormalities. Two months later, clear signs of chronic osteoarthritis in the whole tarsus were present (Fig. 1). In the other three animals, the first radiograph revealed signs of osteoarthritis at different levels in the tarsus, such as narrowing of the joint space (early stage of infection) and osteolytic lesions, and
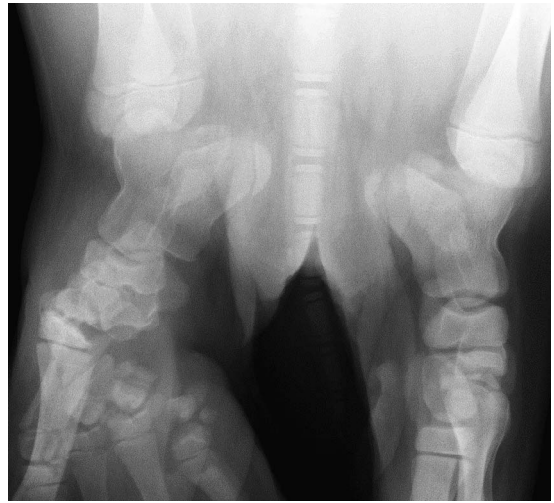

Figure 1. Detail of a radiograph of seal 12-430 2 mo after admission, with clear signs of osteoarthritis in the distal tarsus and in the tarsometatarsal joints. The radiograph at admission revealed soft tissue swelling but no abnormalities at the level of bones and joints.

sclerosis, in one case, resulting in spontaneous amputation (slough; Fig. 2). Bacterial cultures were performed from swabs taken from open wounds of the four seals by Idexx Laboratories, Hoofddorp, The Netherlands (Table 1). The antibiotic susceptibility reports were analyzed, and this resulted in a change of antibiotic treatment to gentamycin (Eurovet Animal Health B.V., 5531AE Bladel, The Netherlands; 2 mg/kg i.m s.i.d.) for 6 days, initiated 2 days prior to surgery.

Figure 2. Spontaneous slough of the left hind flipper developed due to the pressure of inflammation and necrosis of soft tissues, 7 days after admission of seal 12-471.

Table 1. Results of bacterial cultures performed on samples from the four seals, all taken in open wounds, by Idexx Laboratories, Hoofddorp, The Netherlands.

Seal	Aerobic culture	Anaerobic culture
12-430	*Klebsiella oxytoca*	No detection of obligate anaerobic bacteria
	Enterobacter cloacae	
	Streptococcus pyogenes	
12-471	*Pseudomonas aeruginosa*	No detection of obligate anaerobic bacteria
	Eschericia coli (mucoid growth)	
	Aeromonas hydrophila and *Aeromonas caviae*	
	Proteus vulgaris	
	Citrobacter freundii	
12-473	*K. oxytoca*	No detection of obligate anaerobic bacteria
12-486	*E. coli*	No detection of obligate anaerobic bacteria
	E. cloacae	

The four animals were operated upon within a period of 2 days (02 and 03 October 2012). In this small surgical campaign, several elements of the treatment protocol, as adhered to in earlier years, were changed. The operation room was a spacious facility with heating devices. Anesthesia was given in well-controlled circumstances by a team of veterinarians led by a veterinarian specialized in marine mammals anesthesiology (GL). Surgery was performed with better instruments, good diathermia devices, and the presence of an experienced scrub nurse. Moreover, the surgical approach was changed. In previous surgeries, an amputation had been performed as distally as possible, often in the tibiotarsal joint. Now, a more proximal approach was chosen, with the level of amputation at the diaphysis of the tibia and fibula in order to start surgery in a noninfected area (Fig. 3).

Seal status before surgery

Within the first 10 days after arrival, the main parts of the flipper in two seals (12-471 and 12-473) had to be removed under local anesthesia due to partial detachment from the body at the level of the tarsal joint. Seal 12-430 lost some tarsal bones after incision and drainage. The lateral part of the fifth toe was removed under local anaesthesia because of partial detachment. The flipper of seal 12-486, also in a state of detachment, was amputated under general anesthesia.

Anesthesia

The seals were injected with butorphanol (Richter Pharma AG, Oostenrijk, The Netherlands; 0.3 mg/kg i.m) into the lumbar muscles as premedication. After sedation, an i.v. catheter

(Terumo Neolus 0.9 × 70 mm 21G, Terumo Europe N.V., 3001 Leuven, Belgium) was placed in the extradural vein for i.v. fluids, and anesthesia was induced with propofol (Le Vet B.V.; 5mg/kg i.v. until effect). Intubation was done with a cuffed endotracheal tube (Jorvet 34 FR or size 8 mm, Jorgensen Labs, Loveland, Colorado 80538, USA). Manual ventilation was given within a circle breathing system, and anesthesia maintained with isoflurane (Abbott Laboratories Ltd., SL6 4XE Berkshire, United Kingdom) in 100% oxygen, at a concentration between 0.8 and 1.5% throughout the surgery. Heart rate and rhythm were monitored with an oesophageal stethoscope. A rectal probe was used to measure body temperature. Oxygen saturation was monitored

Figure 3. Day seven postoperative radiograph of seal 12-430 showing the level of amputation.

continuously by using a pulse oximeter with the probe attached to the tongue. End-tidal carbon dioxide, together with entry and end-tidal isoflurane were monitored through a capnograph. These parameters were constantly recorded, together with the breathing frequency and breathing volume.

Tumescent anesthesia was given in the areas of the planned incision and the underlying tissues by injecting a fluid composed of saline and a mixture of lidocaine 2% (20 mg/ml) and epinephrine 100,000 (10 µg/ml; Alfasan, 3449JA Woerden, The Netherlands) in a ratio of 4:1. This solution was given in a dose of 1.75 ml/kg of body weight (7 mg lidocaine/kg of body weight and 3.5 µg adrenalin/kg of body weight).

Surgery

The seal was placed in sternal recumbency. The operation field was cleaned, shaved, disinfected, and covered by sterile drapes. The infected area was covered by a sterile bandage and secured with sutures when necessary. Five minutes after injection of the tumescent anesthesia, the surgical procedure started by incising around 4 cm proximal to the insertion of the hind flipper in the back of the seal between the (palpated) fibula and tibia. The bones were denuded over a length of 4 cm by stripping periosteum and adjacent muscles. Then, a segment of 2 cm was removed approximately 4 cm from the tibiotarsal joint with a bone cutter, and the skin incision was lengthened distally around the base of the extremity. Afterwards, the remaining structures (muscles, tendons, vessels, and nerves) were transected from the site of the osteotomies into the direction of the circular part of the incision at the base of the flipper, completing the amputation. This provided good coverage of the cut bones with well-vascularized muscle tissue and skin flaps (attached to the underlying fat and muscle tissue). All large blood vessels and nerves were ligated. Hemostasis was completed with delicate coagulation. The wound was closed with separate Vicryl sutures (4-0 and 3-0), with a few to cover the bone with muscular tissue, a few others in the subcutaneous layer, and most in the skin. A Penrose drain was left in the wound to be removed 2 days later. The suturing resulted in an angled wound with a total length of around 16 cm.

Outcome

The four seals were closely monitored 24 hr after surgery for any postanesthesia or postsurgery complication. They were kept for 1 mo in individual indoor enclosures with access to their own small salt water pool from the second postoperative day onward. Three seals, which were able to eat fish by themselves before surgery, ate and dived normally when they gained access to the water. The fourth (12-486) needed force feeding for another 3 wk before it started eating by itself. They all could enter and exit the pool without incident.

The day after surgery, the drains were removed, with some purulent fluid coming out of the wounds. The surgical wounds were monitored daily and treated topically with chlortetracycline spray (CTC Spray, Eurovet Animal Health B.V.). In seals 12-471 and 12-486, the wounds dehiscenced over several centimeters at the caudal side of the wound at 4 and 3 days postsurgery, respectively, with purulent discharge. One week after surgery, no oozing or further complications were observed in any of the wounds, but topical chlortetracycline was used for one more week.

Gentamycin treatment started 2 days before surgery, lasted a total of 6 days, and was then changed to treatment with enrofloxacin (15, 25, 50, 150 mg tablets, AST Beheer B.V.; 5 mg/kg p.o. b.i.d.) combined with clindamycin (10 mg/kg p.o. b.i.d) for a duration of 4 wk. Carprofen (2 mg/kg p.o. b.i.d.) and tramadol (50-mg capsules, Actavis Group PTC, IS-220 Hafnarfjordur, Iceland; 2 mg/kg p.o. b.i.d) were administered for approximately 2 wk to control inflammation and pain, being removed gradually, depending on the response of the seals.

One month after surgery, the seals were moved to an outdoor enclosure with a larger pool. All of them were able to dive, compete for catching fish, and enter and exit the pool without signs of discomfort and showed no difficulties with moving on land.

A radiologic evaluation was done 1 wk before release. Radiographs were taken of all the seals, and at first, no clear complications were observed (Table 2). The four seals were successfully released 9 wk after surgery. To have a specialist opinion of the radiographs taken in these animals, a radiologist was consulted at a later stage. Evaluation of radiographs of seal 12-471 by the specialist revealed signs of infection not previously appreciated. In seal 12-473, the radiograph before release showed two small translucent areas, which may indicate osteomyelitis.

DISCUSSION

The cause of osteoarthritis in the hind flipper in these four harbor seals remains unknown. One

Table 2. Operation time, estimated blood loss, and result of postoperative radiology.

Seal	Operation time (min)	Estimated blood loss (ml)	Radiographs 2 mo postoperatively
12-430	105	100	No abnormalities
12-471	72	<50	Initially, no abnormalities; retrospective review: signs of osteomyelitis in the tibia
12-473	85	100	No abnormalities but in retrospective review: two small radiolucent areas in tibia were seen, possible signs of osteomyelitis
12-486	90	150	No abnormalities

hypothesis is that it starts with a puncture wound, caused by a bite of another seal, a seagull, a fox, a dog, or maybe by fishing activities. Pups that have lost their mother may seek support from another female seal, and often this leads to aggression that sometimes results in biting the pup. Seagulls tend to attack weakened pups stranded ashore. Human beings accompanied by dogs are a common sight along the coast of the Wadden Sea and on the beaches of the islands, so dog bites may also be a potential cause of puncture wounds in young stranded seals. Predation by coyotes (*Canis latrans*) has been reported as an important cause of death of harbor seal pups in the state of Washington in the USA.[15] Seals may be injured by fishing activities, which is common in the Wadden Sea, not only as bycatch but also by ingestion of fishing hooks or other interaction with fishing equipment.[8,9] The presence of fishing equipment was not observed in any of the 19 seals reported here. If a puncture wound is deep enough, it may introduce microorganisms into joints, which leads easily to an osteoarthritis resistant to the immune system and antibiotics, resulting in a later necrotizing infection.

A vast majority of the seals admitted to the SRRC present with multiple pathologies, of which parasitic pneumonia due to *Otostrongylus circumlitus* or *Parafilaroides gymnurus* or both is the most common. Initial treatment often consists of polydrug treatment: antiparasitic drugs and antibiotics if bacterial infection is present. Most of the 19 pups reported here had comorbidities other than a swollen flipper to justify the administration of an initial treatment with an antibiotic and an anti-inflammatory drug. With this polypragmatic approach, in 15 of the 19 young seals, the inflammation resolved, while in four of them, a clear infection developed with purulent discharge and necrosis. The results of the cultures obtained in the animals showed multiple organisms, most probably the result of a secondary infection. These culture results led the medical team to a change in antibiotic treatment prior to, during, and after the amputation. A better approach may be to consider a deep biopsy of the affected area or to aspirate with a fine-needle (FNA) every swollen flipper at the time of admission to identify the microorganisms involved and give appropriate antibiotics. However, FNA has been suggested to have an accuracy of only 34%.[3] Wound culture should be repeated more frequently to observe overgrowth of other microorganisms or change in resistance patterns.

The final outcome in one or possibly two animals with evidence of osteomyelitis proximal to the level of the amputation, determined by later reviewing of the radiographs postrelease, made the team reconsider the diagnostic and therapeutic approach. Thus, histologic examination of the proximal part of the resected bone should be considered in determining the adequacy of the level of amputation. Moreover a higher level of amputation may be necessary.

The proposed procedure gives a standard surgical approach for the treatment of osteomyelitis of hind flippers in phocids in a relatively clean operation area. This more aggressive approach gives an advantage above dissecting the tarsus or the tibiotarsal joint in an often infected area, where finding the right joint and ideal level of amputation frequently proves difficult. Additional advantages are that the bony ends of the amputated tibia and fibula can be covered easily with healthy muscular tissue, which provides a certain protection against infection, and that the problem of a lack of skin to close the wound, as seen in previous cases, was not encountered. The use of instruments, such as a sharp bone cutter, fine forceps that provide gentle tissue handling, and a good diathermia device in this series, improved surgery as experienced by the first surgeon (KM). However, the final outcome, with osteomyelitis in one or probably two animals in

the proximal part of the tibia, demonstrates that a higher amputation level may be necessary.

The use of diluted local anesthesia (tumescent anesthesia) has become popular in human surgery the last decade as the only anesthetic procedure or in combination with others. Besides an analgesic effect, tumescent anesthesia reduces perioperative blood loss.[5,7,14] The dosage given in the described procedure corresponds with the dosage of tumescent anesthesia for humans and those advised in dogs and cats.[2] In humans, higher doses of lidocaine have been described.[5,7] Pharmacologic studies on the use of lidocaine and epinephrine in marine mammals are not known to us. The clinical impression is that tumescent anesthesia results in less blood loss than the previous approach, which consisted of traditional infiltration of small amounts of undiluted 2% lidocaine with epinephrine (1:100,000) solutions. Moreover, the dilution makes it possible to inject more thoroughly the area to be operated upon, providing, theoretically, more local anesthesia effect. This may decrease the drug doses needed for general anesthesia and thus reduce the risk of anesthesia mortality in seals.

Another clear lesson from this experience is that radiographs taken of the seals should be evaluated by a professional radiologist, if at all possible. Due to this omission, the development of an osteomyelitis was missed in one of the tibias and maybe also in another. From this observation, it is also concluded that if suspicion has been raised of osteoarthritis in a flipper, diagnostic radiologic studies should be done without delay, and that in case of osteoarthritis, surgical treatment should be performed at an early stage and that the level of amputation should be far above the level of osteoarthritis.

The results show that general anesthesia and invasive amputation surgery in harbor seals is feasible. Further development may provide facilities with more invasive procedures and more extensive therapeutic procedures. At present, with the high number of seals in the Wadden Sea, the development of expensive invasive surgical procedures in wild seals may be subject to professional and public debate. However, it is believed that the development of safe surgical and anesthetic procedures in seals can better be done in positive times than in times of impending extinction. Moreover, reliable procedures may facilitate scientific studies on the still poorly understood hemodynamic physiology of seals and in the performance of invasive procedures for the purpose of diagnosis or research.

CONCLUSIONS

In 2012, 4 out of 19 young harbor seals admitted to the SRRC that presented with a swollen hind flipper developed osteoarthritis. The etiology of this infection is not clear. Treatment consisted of a standard amputation at the level of the diaphysis of the tibia and fibula under general anesthesia. Postoperative observation did not reveal problems with moving on land, swimming, diving, and catching fish in a large pool. Although they healed well clinically, in retrospective evaluation, at least one of the animals had clear radiologic signs of osteomyelitis in the proximal part of the tibia. All four seals were brought back to their natural environment.

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