

# Surgical Treatment of Dolphins (*Tursiops aduncus*, *Tursiops truncatus*, *Pseudorca crassidens*, and *Steno bredanensis*) in an Aquarium

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## Abstract

Difficulties associated with therapeutic management vary between large aquatic animals and terrestrial animals. Surgical treatment of large aquatic animals is difficult due to the limitation of facilities and difficulties in postoperative management. For this reason, internal medicine is a likely option for dolphins resident in aquariums, and only a limited number of surgical treatment cases have been reported. Okinawa Churaumi Aquarium has been aiming to provide surgical treatment and postoperative management for their dolphins. Herein, we report four surgical cases, including plastic surgery for a laceration of the dorsal fin and a lymphadenectomy with suturing, all of which yielded satisfactory outcomes. Our findings are as follows: radiography and ultrasound imaging are effective for definitive diagnosis; surgery of approximately 120 min outside the water can be achieved with a modified restraining method; suturing of skin and muscle is possible in dolphins; treatment of a wound by electrocautery is effective for hemostasis; and raising the chlorine concentration in the pool from the normal 0.1 ppm to 2 to 4 ppm after surgery prevents secondary infection of the wound and enables the dolphins to return to the pool immediately after surgery. The efficacy of surgical treatment for common injuries in dolphins was proved by the successful outcomes, and it may be possible to treat more severe cases surgically in the future.

**Key Words:** surgery, postoperative management, dolphin, aquarium, suturing, lymphadenectomy, debridement

## Introduction

Cetaceans are large aquatic mammals, and difficulties associated with their therapeutic management

(e.g., treatment and restraining methods) differ from that of terrestrial animals. Generally, conservative treatment, more precisely internal medicine based on the results of bacteriological and mycological tests is a likely option for treating common injuries in dolphins (small-toothed whales) resident in aquariums. Surgical treatment, even when required, tends to be avoided because of the limitations of facilities and difficulties in postoperative management.

Dolphin skin is composed of the epidermis, dermis, and blubber (hypodermis) and has poor elasticity, making surgical treatment difficult. In fact, only one case of simple skin suturing has been reported (Dierauf, 1990) and then the reported method was not practically useful. Meanwhile, long-term health management of animals kept for display, including dolphins, has recently become the duty of aquariums, suggesting the increasing need for surgical treatment into the future.

Okinawa Churaumi Aquarium in Okinawa, Japan, regularly employs ultrasound imaging, radiography, and computed tomography imaging for accurate diagnosis and proactively performs surgery as a part of the health management of resident dolphins. Herein, we report four cases of surgery, including plastic surgery for a laceration of the dorsal fin and a lymphadenectomy with suturing, all of which yielded satisfactory outcomes.

## Methods

Surgery was first performed on a dolphin at Okinawa Churaumi Aquarium in 2002. Procedures were completed with ordinary surgical equipment in a drained pool or with the animal removed from the water for a short period of time. In each case, chlorine concentration in the nursing pool was increased up to 2 to 4 ppm for 8 h/d to prevent

secondary infection of the wound. Local anesthesia was given to the muscle around the incision site by using a 23-gauge needle. A 0.5 ml agent was injected to 10 to 20 spots around the region. Respiratory rate and body temperature were continuously measured during surgery to monitor the animal's condition.

*Case 1: Plastic Surgery for Laceration of the Dorsal Fin*

A male Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) named "Poi" (body length, 259 cm; body weight, 194 kg) that had been in captivity for 26 y collided with a metal protuberance attached to the pool in April 2002, resulting in a laceration and vascular injury to the dorsal fin. Hemostasis was maintained by electrocautery, but because the wound edges turned upward due to the effect of water pressure during free swimming, the wound remained open (Figure 1-a).

Plastic surgery was performed on the curved part of the dorsal fin 33 d after injury. The body of the dolphin was fixed with restraining bands to a

restraining platform placed in a drained 500 m<sup>3</sup> circular pool (diameter, 5 m; depth, 3 m). An incision at an obtuse angle (against the body) was made to remove the turned-up portions of the wound edge (6 cm × 6 cm) in order to reduce the resistance to water flow. The incision site was treated by electrocautery to stop bleeding (Figure 1-b). The duration of surgery was 30 min. The surgery was performed with local anesthesia only. The animal was very calm and did not show any sign of struggle throughout the procedure.

*Case 2: Plastic Surgery to Reconstruct a Caudal Fin*

A female bottlenose dolphin (*T. truncatus*) named "Fuji" (body length, 270 cm; body weight, 220 kg) that had been in captivity for 26 y developed a bacterial infection on the caudal fin, and insufficient circulation resulted in tissue necrosis (Figure 2-a). Administration of an antibacterial agent and blood transfusion failed to inhibit necrosis, necessitating the surgical removal of the necrotic region where the connective tissue was exposed and curled.



Fig.1-a



Fig.1-b



Fig.1-c



Fig.1-d

**Figure 1.** Plastic surgery for laceration of the dorsal fin in Case 1 — (a) turned-up wound edges on the dorsal fin, (b) surgically treated site immediately after surgery, (c) surgically treated site 20 d after surgery, and (d) surgically treated site 65 d after surgery.

Plastic surgery was performed 23 d after the onset of necrosis. The body of the dolphin was fixed with restraining bands to a restraining platform placed in a drained 500 m<sup>3</sup> circular pool (diameter, 5 m; depth, 3 m). After thermographic examination of the caudal circulation, xylocaine with epinephrine was injected locally into the area adjacent to the resection site. Approximately 75% of the caudal fin (left, right, and dorsal sides) was then removed using an electrotome. Hemostasis also was achieved using the electrotome. The wound was not closed. The duration of surgery was 30 min. The animal did not show any sign of struggle during the surgery and stayed very calm.

*Case 3: Surgical Removal of a Harpoon from the Back*

A female false killer whale (*Pseudorca crassidens*) named “Okigondou No. 4” (body length, 406 cm; body weight, 615 kg) was captured and had been in captivity for 3 y. On arrival at our aquarium in March 2004, a fistula and drainage appeared approximately 10 cm from the dorsal fin towards the head on the left side. Following a marked increase in the amount of discharge from May

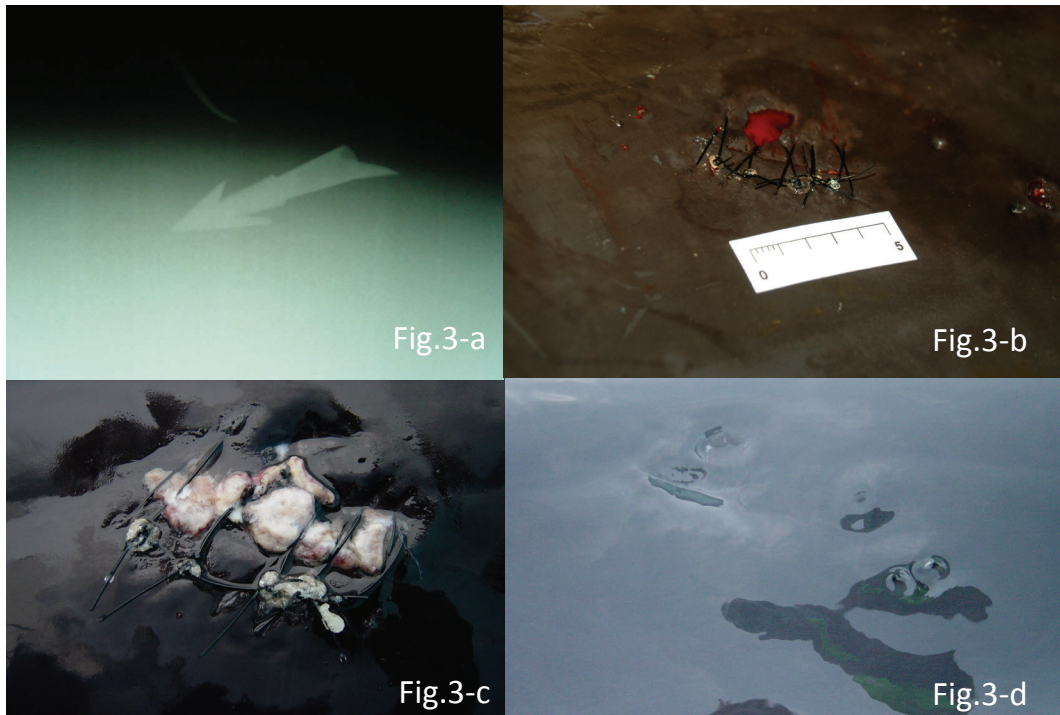
2005, thermography and ultrasound imaging revealed a detachable harpoon head (approximate size, 10 cm) used for dolphin hunting embedded in the dolphin’s back (Figure 3-a).

The harpoon was surgically removed 20 d after imaging diagnosis. Briefly, the dolphin was removed from the pool and restrained on a low-resilience mattress to reduce the compression force from its own body weight, thereby protecting internal organs. The area around the wound (radius, 10 cm) was anesthetized using xylocaine with epinephrine. After confirming the position of the embedded harpoon by ultrasound imaging, a linear incision (approximately 10 cm) was made to the healthy skin from 3 cm outside of the fistula towards the harpoon. The harpoon was removed using forceps. The operative wound was closed by cross-stitching with a nylon suture (USP No. 5, ETHILON 2, Ethicon; Johnson & Johnson Medical Pty Ltd, New Brunswick, NJ, USA) (Figure 3-b). The duration of surgery was 65 min. The dolphin was out of the water for 95 min. The animal did not show any sign of struggle during the surgery and stayed very calm.



**Figure 2.** Plastic surgery for the caudal fin in Case 2—(a) caudal fin before surgery, (b) surgically treated site 3 d after surgery, (c) surgically treated site 60 d after surgery, and (d) surgically treated site 180 d after surgery.





**Figure 3.** Surgical removal of harpoon from the back in Case 3—(a) radiograph of the harpoon, (b) sutured wound, (c) surgically treated site with connective tissues 10 d after surgery, and (d) surgically treated site 60 d after surgery.

#### Case 4: Left Cervical Lymphadenectomy

A male rough-toothed dolphin (*Steno bredanensis*) named “Ra-fu” (body length, 250 cm; body weight, 164 kg) that was captured in September 1998 had a fist-sized swelling in the lower left cervix by the time he arrived at the aquarium. The size of the swelling gradually increased over a 1-y period, accompanied by an elevation of leukocytes (neutrophils). *Staphylococcus aureus* was detected in the pus collected from the swelling by needle aspiration. We administered antibacterial agent CFPM for about 14 d. The swelling was monitored by ultrasound imaging, and the dolphin was rinsed, disinfected, and given antibacterial treatment, respectively. However, the swelling recurred several times and had grown to the size of a softball 1 y later. The general condition of the dolphin had also deteriorated. Ultrasound imaging and anatomical examination led to a diagnosis of lymph node degeneration and the necessity of a lymphadenectomy.

Surgery was performed outside the pool on a stretcher, which was supported by tripods on both ends (Figure 4-a). The area around the wound was anesthetized with xylocaine with epinephrine. Respiration and pulse rate were monitored during surgery. After making a semicircular incision

(protruding towards the tail) around the swelling, the resulting skin flap was pulled towards the head, and the tissue around the mass was dissected to remove the lymph node.

Buried sutures with a single knot were made with an absorbable synthetic suture (USP No. 0, PDS, Ethicon) to close the subcutaneous tissue, while cross-stitching reinforced by overcast-stitching was made using nylon suture (USP No. 5, ETHILON 2, Ethicon) to close the skin. Special care was taken during skin suturing to avoid suture displacement and over-tightening to make sure the wound would fully close to avoid keloid scar formation (Figure 4-b). The duration of surgery was 90 min. The dolphin was out of the water for 125 min. It did not show any sign of struggle during the surgery and stayed very calm.

#### Results

In all cases, hemostasis by electric scalpel was effective to shorten operation time because it enabled hemostasis occurring at the same time as the incision. It was important to ensure debridement in the early perioperative period, which has been done in a drained pool twice a day. In addition, suturing of skin was proven to be possible.



**Figure 4.** Left cervical lymphadenectomy in Case 4—(a) out-of-pool surgery, (b) sutured wound, (c) surgically treated site with connective tissue 55 d after surgery, and (d) surgically treated site 70 d after surgery.

*Case 1: Plastic Surgery for Laceration of the Dorsal Fin*

Blunt debridement was performed twice a day in the drained pool until postoperative day (POD) 9. After removing putrefactive connective tissue, the wound was rinsed with a povidone-iodine solution and coated with a povidone-iodine gel ointment containing sucrose for around 3 min before the pool was refilled. Since granulation tissue reformation was confirmed on POD 10, the same treatment was continued on the dolphin show stage rather than in the drained pool (Figure 1-c). Training made it possible for the dolphin to land on the stage voluntarily and stay there for treatment. Skin covered the wound by POD 62. The wound is no longer visible (Figure 1-d).

*Case 2: Plastic Surgery to Reconstruct a Caudal Fin*

Postoperative management involved blunt debridement and extensive disinfection with povidone-iodine twice daily in the drained pool from POD 2 to 83 (Figure 2-b & 2-c). Granulation tissue reformation was confirmed on POD 3. Once health and feeding had stabilized, the dolphin was trained to present her caudal fin outside the water for

application of the povidone-iodine ointment three to five times a day from POD 84 to 174. The fin was maintained outside the water for at least 3 min after administering the disinfectant. Skin covered the wound by POD 174 (Figure 2-d). Fuji subsequently underwent successful rehabilitation with an artificial caudal fin developed as part of a collaborative project, and her jumping ability is now similar to that of other healthy dolphins (Ueda et al., 2013).

*Case 3: Surgical Removal of a Harpoon from the Back*

The wound was rinsed and disinfected with povidone-iodine twice daily in the drained pool until POD 10 (Figure 3-c). From POD 11 to 14 when the sutures were removed, the same disinfectant procedure was performed once daily. The suture site healed by POD 43, and the fistula had closed by POD 60 (Figure 3-d).

*Case 4: Left Cervical Lymphadenectomy*

Blunt debridement and extensive disinfection with povidone-iodine were performed twice daily in the drained pool from POD 2 to 36. Sutures were removed on POD 20. The dolphin was trained to accept the treatment provided from POD 37 to 70

when the wound was covered with normal skin. Povidone-iodine was applied four times daily: once in the drained pool and three times when the affected region was held above the water surface (Figure 4-c & 4-d). The treated region was kept outside the water for at least 3 min after the administration of disinfectant. Pathological examination of the removed mass revealed suppurative granulomatous lymphadenitis.

### Discussion

Japan has a large number of aquariums housing a wide variety of organisms, but veterinary knowledge and clinical cases are limited. Dolphins are the most popular animals among those displayed at aquariums, but because they are aquatic, it is difficult to examine and treat them using the approaches commonly performed on terrestrial animals.

In addition, replacement of dolphins has been relatively easy, and thus surgical treatment has historically not been undertaken. However, in recent years, appropriate dolphin care, husbandry, and health management have become paramount, especially in view of animal welfare. Furthermore, maintaining aquatic animals by captive breeding, not by the purchasing of wild animals, has become one of the duties of aquariums. Under such circumstances, animals are kept in aquariums for a longer period of time, and surgical approaches become necessary for treating common injuries as well as more serious disease. For this reason, we started research on the health management of animals and its technical development ten years ago.

We have performed dissection, excised a lesion after making a skin incision, and sutured wounds to achieve satisfactory closure and wound healing—procedures that had previously been challenging in dolphins. Our results clearly suggest that dolphins can be treated surgically by appropriate procedures.

We had previously shown that the use of a low-resilience mattress and a stretcher while restraining a dolphin reduces the stress of internal organ compression (Suzuki et al., 2008), thereby enabling surgical treatment of more than 2 h outside the water. In domestic animals, sutures were usually removed 7 d after surgery (Nakamura, 1993); but in aquatic animals (dolphins), the time required for postoperative healing is longer, partly due to their unique skin structure. We considered that if necrotic tissue was not removed from around the wound during the long recovery period, it would cause secondary infection and inhibit the formation of granulation tissue. Therefore, we proactively cleaned

and performed debridement soon after surgery. To ensure debridement and good wound observation, it is significant to establish systems for pool drainage and to train the dolphins to follow necessary instructions. In addition, disinfecting procedures must be performed out of the water and for a sufficient time in order for the application to be effective. Moreover, raising the chlorine concentration in the pool from the normal 0.1 ppm to 2 to 4 ppm after surgery prevented secondary infection of the wound and enabled the dolphins to return to the pool immediately after surgery.

We hope that by reporting the favorable surgical outcomes we have achieved over the years other aquariums will be encouraged to treat dolphins surgically in the future. An increase in the number of surgical cases will lead not only to advances in surgical procedures but also to advances in anesthetic management technology.

The onset of neoplastic diseases in aquarium animals due to ageing is of particular concern. In order to treat such cases surgically, the following aspects need to be addressed: various diagnostic systems; methods for restraint and anesthesia to reduce stress; and further advances in intraoperative monitoring, surgical procedures, and perioperative management.

### Acknowledgments

We thank the aquarium veterinarian, Dr Makio Yanagisawa, and the keepers responsible for perioperative management.

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