J. Field Ornithol., 70(2):244–250

LOSS FROM HARLEQUIN DUCKS OF ABDOMINALLY IMPLANTED RADIO TRANSMITTERS EQUIPPED WITH PERCUTANEOUS ANTENNAS

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Abstract.—We documented extrusion and loss of abdominally implanted radio transmitters with percutaneous antennas from adult female Harlequin Ducks (*Histrionicus histrionicus*). Birds were captured during wing molt (late August to mid-September) in 1995–1997. Of 44 Harlequin Ducks implanted with radios and recaptured, 7 (16%) had lost their transmitters and 5 (11%) had radios in the process of extruding. Most (11 of 12) extrusions and losses occurred in birds implanted with radios in 1996 and recaptured in 1997. We suggest that transmitter extrusions and losses were due largely to changes in transmitter design made between 1995 and 1996. Transmitters implanted in 1996 were cylindrical rather than spherical, had a flat end with an abrupt edge, and the lower portion of the antenna was reinforced. Radio losses occurred after the 7-mo monitoring period and caused no apparent harm to the birds. Investigators using implanted radios with percutaneous antennas for long-term projects should be aware of the potential for radio extrusion and should minimize the problem by using transmitters that have no sharp edges and that are wide, rather than narrow.

PÉRDIDA DE RADIOTRANSMISORES EQUIPADOS CON ANTENAS PERCUTÁNEAS IMPLANTADOS ABDOMINALMENTE EN *HISTRIONICUS HISTRIONICUS*.

Sinopsis—Documentamos la extrusión y pérdida de radiotransmisores equipados con antenas percutáneas implantados abdominalmente en hembras adultas de *Histrionicus histrionicus*. Las aves se capturaron durante la muda de las alas (fines de agosto a mediados de septiembre) en 1995–1997. De 44 aves implantadas con radios y recapturados, 7 (16%) habían perdido sus transmisores y 5 (11%) tenían los radios en el proceso de extrusión. La mayoría de las extrusiones y pérdidas (11 de 12) ocurrieron en aves implantadas con radios en 1996 y recapturadas en 1997. Sugerimos que las extrusiones y pérdidas de transmisores se debieron en su mayoría a cambios en el diseño de transmisores producido entre 1995 y 1996. Los transmisores implantados en 1996 fueron cilíndricos más que esféricos, tenían un fondo plano con un borde abrupto, y la porción inferior de la antena fué reforzada. Las pérdidas de radios ocurrieron después del período de monitoreo de 7 meses y no causó ningún daño aparente a las aves. Los investigadores usando radios implantados con antenas percutáneas

en proyectos de largo plazo debían estar conscientes del potencial de extrusión de los radios y debieran diseñar transmisores que no tengan bordes cortantes y que sean anchos en contraste a finos para minimizar el problema.

Radio telemetry has been used widely in studies of wildlife survival, movements, habitat use, and breeding. An increasing body of literature suggests that radio transmitters surgically implanted into wild waterfowl are less disruptive than transmitters that are externally attached, based on differences in survival or return rates (Ward and Flint 1995, Dzus and Clark 1996), behavior (Pietz et al. 1993), and reproductive rates (Pietz et al. 1993, Rotella et al. 1993, Ward and Flint 1995, Paquette et al. 1997). The disadvantages of externally mounted transmitters stimulated the development of techniques for surgical implantation of transmitters (Korschgen et al. 1984, Olsen et al. 1992, Korschgen et al. 1996).

Waterfowl studies using implanted transmitters have reported high rates of success (e.g., Olsen et al. 1992, Haramis et al. 1993, Hohman et al. 1993, 1995). Loss of an internal transmitter has been documented only once, when a transmitter with an internal antenna was passed through the oviduct of a nesting female (Garrettson and Rohwer 1996). In this paper, we document the occurrence of extrusion and loss from Harlequin Ducks (*Histrionicus histrionicus*) of abdominally implanted radio transmitters with external antennas and we offer recommendations to minimize this problem.

METHODS

We surgically implanted radio transmitters into adult female Harlequin Ducks from 1995–1997 as part of a study of their over-winter survival in Prince William Sound, Alaska. We captured birds and implanted transmitters each year during the last week of August through the third week of September during annual wing molt (when birds were flightless). Each bird was banded with a unique U. S. Fish and Wildlife Service (USFWS) aluminum leg band, which allowed identification of recaptured birds.

The procedure described by Korschgen et al. (1996) was used to implant transmitters surgically. Briefly, anesthesia was induced and maintained with isoflurane (Aerrane, Ohmeda, Liberty Corner, New Jersey). Following pre-surgical preparation, a midline incision was made into the abdomen and the right abdominal air sac was breached. The antenna was passed through a trochar inserted from outside the bird and placed as dorsally as possible at the intersection of the right pubic bone and the synsacrum. The transmitter was fitted into the right abdominal air sac and the incision was closed with absorbable sutures. The only attachment of the transmitter to the body of the duck consisted of a single interrupted suture through the skin, body wall and the collar at the base of the antenna. Birds recovered from anesthesia for at least 1 h before being released at the sites of their capture. Surgeries were done in a covered but unheated workspace on the aft deck of a chartered motor vessel.

The transmitters (ATS, Isanti, Minnesota) we used in 1995 weighed 15

TABLE 1. Fate of radio transmitters implanted into female Harlequin Ducks during wing molt, Prince William Sound, Alaska, 1995–1997.

Year Implanted/ Recaptured	*N*	Radios lost	Radios retained		
			Undamaged	Antenna broken	Radio extruding
1995/1996	17	0	4	13	0
1995/1997	4	1	0	3	0
1996/1997	23	6	10	2	5
Totals	44	7	14	18	5

g and were embedded in resin, which resulted in a roughly spherical shape (1.7–2.4 cm diameter). The transmitters (Holohil Systems, Carp, Ontario, Canada) we used in 1996 weighed 17.5 g and were enclosed in brass cylinders coated with a bio-compatible compound and measuring 4.0 cm by 1.5 cm. All transmitters had wire whip antennas with a dacron-covered sleeve glued to the base of the antenna. To deter birds from breaking antennas, rubber reinforcement was added to the basal 4 cm of the antennas in 1996, which extended 3 cm outside of the body.

In the second and third years of the study, we recaptured some birds that had been implanted with transmitters in a previous year. The presence of one of our leg bands and an external antenna or a visible antenna stump immediately identified a retained radio. We palpated the abdomens of all recaptured and transmitter-implanted birds to detect non-functioning radios that lacked a visible antenna stump and used a radio receiver, tuned to the proper frequency and placed immediately adjacent to the bird, to determine the presence of a functioning radio. In 1996 and 1997, most birds with non-functioning or missing radios were re-implanted with a new radio. After the abdomen was opened, a visual and tactile inspection was made of all accessible spaces in the abdomen and abdominal air sacs. We radiographed several birds in 1997 using a portable radiograph machine (Bowie Portable X-Ray Generator, Bowie Manufact., Lake City, Iowa) and instant film (Polaroid Transparent Radiographic Instant Film, Type TPX) to confirm that the transmitters had, indeed been lost, rather than migrated into the anterior thorax of the birds.

RESULTS

We recaptured 44 ducks in 1996 and 1997 that had been implanted with radios in 1995 or 1996 (Table 1). Of the 40 ducks that were recaptured 1 yr after radio implantation, 6 (15%) had lost their transmitters and 5 (13%) had radios that were in the process of extruding (Table 1). Of the 17 ducks implanted with spherical transmitters in 1995 and recaptured in 1996, 13 had broken off the antenna where it exited the skin, leaving either no stump or only 1–2 mm of antenna extending from the skin. None of the birds implanted in 1995 had lost the transmitter when

recaptured in 1996. The transmitter was missing from one of the four birds implanted in 1995 and recaptured in 1997; the antennas were broken off of the transmitters in the other three birds (Table 1). We could palpate the transmitters in the caudal right quadrant of recaptured ducks as a firm mass of appropriate size and shape.

In 1997, we recaptured 23 ducks implanted with cylindrical transmitters in 1996. Of these, 12 (52%) had radios present, with no sign of extrusion; 2 of the 12 ducks had broken off the antennas at the end of the reinforced base (Table 1). Three birds (13%) had radios present internally, but with the dacron antenna collar pulled out through the body wall and skin, two birds (9%) had pulled both the dacron antenna collar and part of the transmitter out through the skin, and six birds (26%) had lost their radios entirely. In 1997, we confirmed by radiography for three ducks that the transmitters had been entirely lost from the body instead of having migrated to another location within the body.

We replaced 20 radios in recaptured birds 1–2 yr after the first implantation. During these surgeries, extensive adhesions were found involving intestines, air sac membranes, liver, and the ventral body wall. A thick (1–2 mm) fibrous sheath completely surrounded the entire transmitter body and had to be cut to remove the enclosed transmitter. The adhesion between the antenna collar and the body wall was broken by gently pulling on the transmitter body. Hemorrhage was minimal from the incised connective tissue sheath and the disrupted antenna collar attachment site.

We captured two birds in 1997 with the transmitters partially protruding through the body wall. In these birds, the arc of the caudal end of the transmitter body closest to the antenna attachment had been pulled first and farthest through the body wall, suggesting that a lever action had been applied to the reinforced base of the antenna. The fit between the skin and the transmitter body was tight, preventing both the immediate loss of the transmitter and the leakage of water into the abdomen, which might have caused infectious peritonitis or air sacculitis. We removed both transmitters, after aseptic preparation of the site, by applying traction to the antenna base and gentle clearing of inflammatory debris from around the skin-transmitter interface, using the blunt end of a scalpel handle. We surgically reduced and closed the resulting fistulae.

DISCUSSION

All attachments to wild animals, such as tags, bands, marks, and instrument packages, suffer a rate of loss specific to the species of animal, environmental conditions, type of attachment, and mechanism of attachment. We chose abdominal implantation of radio transmitters for this project because of the potential deleterious effects of externally mounted transmitters (Pietz et al. 1993, Rotella et al. 1993, Ward and Flint 1995, Dzus and Clark 1996, Paquette et al. 1997). Loss rates of surgically implanted transmitters are often assumed to be low (Zimmer 1997) compared to externally attached transmitters with only one documented loss of an implanted transmitter reported (Garrettson and Rohwer 1996). Be-

cause abdominally implanted transmitters equipped with internal coiled antennas suffer reduced signal strength due to the body mass of the animal, we used percutaneous antennas. The technique developed by Korschgen et al. (1996), utilizing a percutaneous antenna was used in one study without report of transmitter loss (Petersen et al. 1995).

We believe that the increased rate of loss of transmitters implanted in 1996 compared to those implanted in 1995 resulted from changes in dimensions and configurations of the transmitters. In 1995 the transmitters were rounder and wider than the cylindrical transmitters used in 1996. The 1995 transmitters were built by constructing the electronics around the partial circumference of a cylindrical battery and then embedding both in epoxy resin, resulting in a spherical shape. Only one bird that had been implanted in 1995 and recaptured in the 2 yr following implantation had lost it's transmitter. The 1996 transmitters and batteries were enclosed in a cylindrical brass case, lightly coated with a biocompatible material. The flat posterior end of the brass case met the curved side wall in an abrupt, 90 degree angle, which was inadequately blunted by the biocompatible coating. The antenna exited the side of the brass case adjacent to this sharp angle. A final change in design was the addition of rubber reinforcement around the initial 4 cm of antenna, in an effort to reduce the bird's ability to break the antenna at the level of the skin.

We speculate that the birds groom and manipulate the solid wire antenna, causing metal fatigue and failure where the antenna exits the skin, as documented with the 1995 transmitters. The additional reinforcement material added to the base of the antennas in 1996 reduced the antenna failure rate, although some birds still managed to break the antenna at the distal end of the reinforcement. The birds likely continued to groom and manipulate the remaining, reinforced antenna base until they pulled the antenna collar out through the body wall. Adhesions, contractures, and proliferative connective tissue prevented the transmitter from then falling back into the air sac and drawing the antenna back into the bird. The placement of the antenna on the side of the cylindrical transmitter body next to the flat end caused a lever action when the bird pulled on the antenna base. This placed the abrupt edge of the transmitter's flat end adjacent to the body wall, which helped to enlarge the hole where the antenna exited. Eventually the entire transmitter was pulled through the fistula.

The smaller cross-section of the cylindrical transmitter used in 1996 was able to pass through a smaller fistula. Also, the narrower transmitter probably could pass more easily through the angle formed by the pubic bone and the synsacrum. To reduce this effect, the surgeon must assure that the antenna is passed through the body wall as dorsally as possible at the origin of the pubic bone on the synsacrum. The angle between these two anatomical structures narrows dorsally, and the intersecting soft tissues are thicker and stronger dorsally.

There have been few reports of long-term retention rates because ab-

dominal implantation of transmitters in birds, especially those using percutaneous antennas, is a relatively new technique. The transmitter with a percutaneous antenna that we used is anchored in the short term by a suture through the antenna collar and body wall and in the long term by the body wall attachment to the antenna collar that occurs during healing. Therefore, there is little chance for the transintestinal expulsion of transmitters experienced in ictalurid and salmonid fishes (Summerfelt and Mosier 1984, Chisholm and Hubert 1985, Marty and Summerfelt 1986).

All of the ducks that had lost transmitters and were recaptured in fall 1997 had been located regularly from August–September 1996 through April 1997. Therefore, transmitters must have been lost between the end of April and the time the birds were recaptured in late August and September 1997. Loss of transmitters did not appear to affect the health of implanted ducks. Recaptured birds with lost or extruding transmitters appeared healthy. The fibrous sheath that developed around the transmitter body may have sealed the transmitter from the air sac and peritoneal cavity during extrusion of the transmitter through the skin. Recapture rates in the year following implantation were higher for birds implanted in 1996 (24%) than in 1995 (19%) suggesting that survival was not compromised by loss of the transmitter.

We believe that the loss of abdominally implanted transmitters can be reduced by designing wider transmitter bodies with no abrupt edges, careful placement of the percutaneous antenna as dorsally as possible and elimination of the reinforcement at the base of the antenna. We recommend that investigators using implanted transmitters with external antennas work closely with manufacturers to design a transmitter that is appropriate for their work and which minimizes risk of extrusion and loss. Loss of radios could result in erroneous conclusions in studies relying on radio telemetry.

ACKNOWLEDGMENTS

These data were collected under studies supported by the Exxon Valdez Oil Spill Trustee Council. However, the findings and conclusions presented by the authors are their own and do not necessarily reflect the views or position of the Trustee Council. Data were collected with the assistance of Bryan Baetsle, Rick Ballas, Brad Benter, Tim Bowman, Kathy Burek, Jennifer DeGroot, Bob Jarvis, Danielle Mather, Dan Monson, Julie Morse, Dan Ruthrauff, Dorcas Schaeffer, Kim Trust, and the crews of the motor vessels *Auklet, Julia Breeze, Kittiwake II,* and *Waters.* D.V. Derksen, J.B. Grand, and T. Van Pelt reviewed the manuscript. Use of trade names does not imply product endorsement.

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Received 11 Mar. 1998; accepted 30 Jul. 1998.