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IMMOBILIZATION OF FREE-RANGING MALE PACIFIC WALRUSES (*ODOBENUS ROSMARUS DIVERGENS*) WITH CARFENTANIL CITRATE AND NALTREXONE HYDROCHLORIDE

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The major challenges in immobilization of free-ranging walruses (*Odobenus rosmarus divergens*) are to produce a deep level of anesthesia very quickly (to avoid darted animals from entering the water and drowning), and to find a drug or drug combination that requires only a small volume to be delivered by dart, is safe, reversible, and that provides an adequate period of immobilization to permit attachment of instruments, phlebotomy, and measuring. Tiletamine-zolazepam is recommended for immobilization of pinnipeds, with inhalant anesthesia recommended for more extensive procedures requiring better analgesia (Gales 1989). Drugs

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that have been used on free-ranging walruses include ketamine (Hagenbeck *et al.* 1975), phencyclidine combined with acepromazine (DeMaster *et al.* 1981), etorphine (Born and Knutsen 1990, Hills 1992, Griffiths *et al.* 1993), tiletamine-zolazepam (Stirling and Sjare 1988, Griffiths *et al.* 1993), medetomidine and ketamine (Lydersen *et al.* 1992), and carfentanil (Hills 1992, Lanthier *et al.* 1999). Carfentanil but not etorphine is presently licensed and available in the United States.

Forty-eight adult male walruses were immobilized with carfentanil citrate in the summers of 1995–1997 at Maggy Beach (58°57′N, 161°76′W), a land haul-out located at Cape Peirce within the Togiak National Wildlife Refuge in southwest Alaska. The number of animals present during immobilizations ranged from three to several thousand. Criteria for choosing individual walruses included good body condition, the presence of two tusks of sufficient diameter for the attachment of radio transmitters, and presence of the animal at the edge of the herd. In addition, we chose animals that were resting quietly and which had not recently hauled out (as judged by skin color). Walruses were darted from ranges of approximately 10–15 m using a Cap-Chur rifle (Palmer Chemical and Equipment Co., Douglasville, Georgia, GA 30133). Carfentanil citrate (Wildlife Pharmaceuticals, Fort Collins, CO 80524) was administered by dart with a 10-cm needle to the lumbar region. Most animals received a dose of 2.7 or 3.0 mg of carfentanil. One animal received a second dose after the first syringe apparently burst on impact. Induction times were measured as being the time at which the animal collapsed, failed to respond to external stimuli, or as the time when the darter stood up and moved towards the animal.

Carfentanil anesthesia was reversed with naltrexone hydrochloride (Wildlife Pharmaceuticals, Fort Collins, CO 80524) administered with an 18-gauge, 10-cm needle or with a 14-gauge over-the-needle catheter into either the epidural venous sinus or the caudal gluteal vein. After experiencing some deaths, we adopted a protocol wherein at 11 min postdarting with carfentanil (or as soon thereafter that we could approach the animal), we gave 150 mg of naltrexone hydrochloride IM and a second dose of 150 mg naltrexone IM or IV was given at 13 min postdarting. Intramuscular injections of naltrexone were placed into the tongue, the upper lip, or the shoulder muscles. If IV access was available, an additional 150 mg of naltrexone was given IV after all handling was finished. Recovery times were calculated from the time of first injection of naltrexone until the animal could raise and support its head. Recovery times could not always be determined because of positioning of the animals and a tendency for them to remain recumbent, with their heads down, following recovery. The close presence of other walruses often prevented continual observation of the head. We observed handled walruses for up to three hours after recovery, when possible. An unpaired *t*-test was used to examine differences in induction or recovery times for animals given either 2.7 or 3.0 mg carfentanil. We allowed several hours between capture sessions to permit the herd to settle and to reduce the likelihood of treated animals from entering the water.

Six of 48 (13%) adult male Pacific walruses died from immobilization (Table 1). Doses of 2.0 or 2.4 mg of carfentanil did not immobilize two walruses (Table 1). Using a carfentanil dose of 2.7 or 2.85 mg, only 1 of 28 (4%) animals died. That death was attributed to trauma at induction by being trampled by neighboring

Table 1. Summary of carfentanil doses and deaths of male Pacific walruses (1995–1997).

Carfentanil dose (mg)	Number of animals	Number dead
2.0	1[a]	0
2.4	1[a]	0
2.7	22	0
2.85	6	1[b]
3.0	16	3
4.0	1	1
5.25	1[c]	1

[a] Not immobilized.
[b] Death due to trauma from being trampled.
[c] Dart with 3.0 mg carfentanil exploded on impact; animal not immobilized. An additional 2.25 mg carfentanil was given 44 min later. After reversal, animal moved towards water, buried its tusks in sand and suffocated.

animals that tried to move away upon approach of the capture crew. When a carfentanil dose of 3.0 mg or greater was administered, 5 of 18 (28%) animals died (Table 1). One animal died from suffocation due to hyperflexion of the trachea while moving down the sloped beach towards the water. It is probable that this animal was still heavily sedated despite the administration of naltrexone. Necropsies were done on another four dead animals, but no pathology contributory to death was found. The deaths were undoubtedly directly related to the administration of narcotic anesthesia, but the exact pathophysiologic mechanism remains unknown.

Reactions to being darted varied from no reaction to a sudden rising of the head, rarely followed by the animal moving farther into the herd. Only one animal moved into the water after being darted. Most walruses raised their heads upon being darted but lowered their heads again when no threat was perceived. The first signs of the drug taking effect were a rising of the head and a twitching of the muzzle, followed by twitching of the head and neck. Twitching progressed to generalized body spasms, and finally, there was a general collapse. Sometimes the animal did not raise its head, or suspended its head by resting its tusks on another animal or on the beach. In those cases, accurate induction times could not be recorded. With those animals, induction times were considered to be the times at which the biologist stood up to approach the immobilized animal (without it reacting to the stimulus).

Induction periods varied greatly within dosage levels (Table 2). Induction periods were not significantly different (unpaired t-test, $P = 0.344$) between dosage levels of 2.7–3.0 mg carfentanil. Upon approach, most animals were rigid, with bulging eyes and no observable respiration. Typically, spontaneous respiration had not begun at the time that the first administration of naltrexone was given. Times of recovery were sometimes difficult to observe because of body position and a tendency of the walruses to remain recumbent as they recovered. Recovery periods varied from 5 to 37 min from the initial dose of naltrexone (Table 2). Mean recovery periods were not significantly different (unpaired t-test, $P = 0.255$) between dose levels of 2.7–3.0 mg carfentanil.

Carfentanil at a dose of 2.7–3.0 mg was effective at rapidly immobilizing adult male walruses on a land haul-out. Carfentanil immobilization of Pacific walruses

Table 2. Mean induction and recovery periods (min) of male Pacific walruses immobilized with different doses of IM carfentanil delivered by dart. Data are given only for walruses receiving a single dose of carfentanil, for which induction occurred, and for which induction or recovery times were recorded. In some cases, induction times were considered to be the time the darter rose to a standing position to move the remainder of the herd away from the darted animal. Recovery times were calculated from the time of the first injection of naltrexone.

	Induction periods (min)				Recovery periods (min)			
Carfentanil dose (mg)	*n*	Mean	SD	Interval	*n*	Mean	SD	Interval
2.7	18	10	5	4–20	10	11	5	6–18
2.85	4	7	3	5–12	1	11	–	–
3.0	15	8	4	2–14	11	15	9	5–37
4.0	1	7	–	–	–	–	–	–

resulted in muscle spasms, which have been noted in six Atlantic walrus (*Odobenus rosmarus rosmarus*) immobilized with carfentanil (Lanthier *et al.* 1999). This reaction made manipulation of the animals more difficult and prevented placing of an endotracheal tube, which would have allowed assisted respiration. All walruses were apneic for an extended period after being darted with carfentanil.

Because of unpredictable immobilization duration and quality, we did not weigh walruses. Hills (1992) used carfentanil to immobilize four adult male walruses, but two of them were found dead within a week after immobilization, from unknown causes. She estimated body weights of immobilized male walruses to be 750–1,300 kg and female walrus body weights to range from 450 to 800 kg. Considering that we determined the useful dose range for carfentanil to be only 0.3 mg (from 2.7 to 3.0 mg), variation in body mass could cause the dosage of carfentanil to vary enormously. This likely resulted in under- and over-dosing of some animals. Lanthier *et al.* (1999) estimated 4–5 μg/kg as an effective dosage for Atlantic walrus; however, they immobilized only six animals and only estimated the weights of three animals.

A major problem with the use of carfentanil was the short handling period that it allowed. To extend the working time while maintaining a degree of immobilization sufficient to handle the animal, we injected one-half doses (150 mg) IM of naltrexone into an immobilized animal at 11 and 13 min postdarting. Administration of the antagonist began the recovery period. We believe that our strategy for administration of the antagonist drug reduced mortality. The slower absorption kinetics of IM administration of drugs required the early administration of drugs to prevent mortality due to respiratory arrest and anoxia. The IM dose was administered in two aliquots to slow recovery of the animal and to permit IV access to be gained. We administered both IM doses of naltrexone regardless of whether or not IV access was gained.

Lanthier *et al.* (1999) successfully immobilized six male Atlantic walruses with 4 mg of carfentanil without mortality, a dose that we found to be unacceptable in Pacific walruses. Like us, they reversed the opioid with naltrexone. If used under conditions similar to ours, we suggest that a dosage of 4 mg/kg for walrus immobilization is likely to result in mortality.

Some variation in induction times (2–20 min) in our study may have been due to inadvertent variations in dosage, given that animals were not weighed, variations in injection placement (possible whole or partial injection of the drug into blubber, rather than into muscle), and difficulties in determining exactly when it was safe to approach a darted animal. Individual animal variations in susceptibility to the drug, variations in body weight for a given dose of opioid, and differences in placement of the dart may have a greater effect on induction time than small variations in the dose of carfentanil. Inadvertent injection into a vein or venous plexus may have accounted for occasional induction times of a few minutes or less. Long induction times (>5 min) may not be acceptable for immobilizing female walruses lying on the edge of an ice flow, where the animal might slide or be pushed into the water.

Improvements in immobilization of free-ranging walruses will be required to facilitate further biological research. The goal will be to develop an anesthetic protocol that maintains the rapid induction times experienced with carfentanil, to increase the safety level, to refine monitoring techniques and instrumentation, and to increase the handling time available to walrus researchers.

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