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CHEMICAL ANESTHESIA OF NORTHERN SEA OTTERS (*ENHYDRA LUTRIS*): RESULTS OF PAST FIELD STUDIES

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Abstract: Between 1987 and 1997, we chemically immobilized 597 wild sea otters (*Enhydra lutris*) in Alaska for the collection of biological samples or for surgical instrumentation. One drug-related sea otter fatality occurred during this time. Fentanyl in combination with diazepam produced consistent, smooth inductions with minimal need for supplemental anesthetics during procedures lasting 30–40 min. Antagonism with naltrexone or naloxone was rapid and complete, although we observed narcotic recycling in sea otters treated with naloxone. For surgical procedures, we recommend a fentanyl target dose of 0.33 mg/kg of body mass and diazepam at 0.11 mg/kg. For nonsurgical biological sample collection procedures, we recommend fentanyl at 0.22 mg/kg and diazepam at 0.07 mg/kg. We advise the use of the opioid antagonist naltrexone at a ratio of 2:1 to the total fentanyl administered during processing.

Key words: Anesthesia, diazepam, sea otter, *Enhydra lutris*, fentanyl, naltrexone.

INTRODUCTION

Researchers have captured several thousand sea otters throughout their range since the 1950s for translocation, tagging, and collection of biologic samples. Capture methods have been well described[5] and include modified gill nets (also called tangle nets), dip nets, and diver-operated Wilson traps. Tagging and surgical procedures for the implantation of radiotelemetry transmitters have changed little since they were developed.[10,27] However, chemical anesthesia protocols have changed. Researchers administered ''antistress'' drugs during translocation projects as early as 1959.[5] Full chemical anesthesia protocols were developed for instrumentation and veterinary care.[15,23,26,28] However, published protocols, although appropriate for clinical settings, gave dosages lower than those we found necessary for wild, healthy sea otters. Here, we describe drug combinations used in Alaska from 1987 to 1997 and recommend dosages for routine biologic sampling and surgical procedures for wild sea otters.

METHODS

Study area

We captured sea otters along the northern Pacific Rim from Vancouver Island, British Columbia, to Attu Island, Alaska, at the western end of the Aleutian Island chain. Most captures occurred within Prince William Sound in south-central Alaska or at Amchitka Island in the Aleutian chain. The otters were captured for the collection of biologic samples and, in some cases, for surgical procedures.[6,8,9,19,20]

Capture and anesthesia

Several capture techniques were employed, including tangle nets, dip nets, and Wilson traps.[5] Estimated body weights of sea otters were used to calculate the induction dose, which was administered by i.m. injection to the hind limb with a handheld syringe. Two drug combinations were used: fentanyl citrate (RBI, Natick, Maine 01760, USA) combined with azaperone (Stresnil®, Pitman-Moore, Washington Crossing, New Jersey 07882, USA) and fentanyl combined with diazepam (Steris Laboratories, Phoenix, Arizona 85043, USA).

Until 1991, sea otter research personnel used a combination of fentanyl and azaperone to anesthetize otters. After 1991, azaperone was no longer readily available, and diazepam was used instead. Supplemental i.m. injections of fentanyl were administered as required to maintain an adequate level of anesthesia for the procedures. After 1991, supplemental i.m. or i.v. injections of diazepam (0.5–1.5 mg) were administered as needed to control seizures.

Anesthetized otters were weighed, and actual drug doses were calculated. Induction time was measured opportunistically (minutes from injection until fully anesthetized) in a subset of 101 animals. Rectal temperature, gum color, and capillary refill were all monitored throughout the period of sedation and handling. At least one measurement of heart rate and respiration rate was often recorded during handling (generally within 10 min of complete anesthetization). The time of drug injections, procedures such as body temperature readings, and presence of tremors or convulsions were recorded,

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and the time to first procedure (TFP) was used as an index of induction time.

After the completion of all procedures, an i.m. injection of either naloxone (Wildlife Pharmaceuticals, Fort Collins, Colorado 80524, USA) or naltrexone (Trexonil®, Wildlife Pharmaceuticals) was administered at a dose equal to 1.5–3 times the total fentanyl dose administered as an opioid antagonist. The use of naloxone was discontinued in 1992, when naltrexone became available. The antagonist was always drawn up before administering the initial fentanyl injection so that it would be immediately ready for use if needed.

Before 1990, fentanyl was antagonized with i.v. and i.m. injections of naloxone (half the total dose by each route) at the water's edge, and the otters were released to the water as soon as a conscious ''head-up'' response was observed, generally within 30 sec after injection. However, naloxone has a prominent first-pass effect mediated by the liver in some species[11] and thus may have a shorter half-life than fentanyl. Consequently, the narcotic can ''recycle,'' allowing the animal to return to a state of anesthesia if the naloxone is eliminated before the fentanyl is completely metabolized. Between 1990 and 1992, otters were released to floating net pens and observed for 1–2 hr after antagonism, because of concerns about possible narcotic recycling. Because signs of narcotic recycling were frequently observed (e.g., rolling face down in the water and being nonresponsive to stimuli, which was remedied by additional antagonist), the practice of giving supplemental naloxone at a dose equal to half the initial dose just prior to release from the net pen was intiated. Beginning in 1992, naltrexone replaced naloxone, and because of its longer half-life extended holding times and administration of supplemental antagonist were deemed unnecessary. After 1992, only an i.m. injection of naltrexone was administered, and the otter was held within a capture box until fully alert (usually 1–3 min) before being released to the water.

Data analysis

The effectiveness of these drug doses and combinations was examined using logistic regression and the Wald chi-square statistic to explain the occurrence of four anesthetic response variables (coded as 1 = yes, 2 = no): 1) supplemental fentanyl required for complete anesthesia or to complete procedures, 2) tremors or convulsions observed during anesthesia, 3) hyperthermia reached during anesthesia (defined as body temperature reaching 40°C), and 4) narcotic recycling observed following fentanyl antagonism. Full models compared drug combinations (i.e., fentanyl with synergist azaperone vs. diazepam, or antagonist naloxone vs. naltrexone) and doses. Doses among drug combinations are highly correlated; thus, we used only one drug dose in any one model (i.e., one model may include fentanyl dose and synergist type and a second model may include synergist type and synergist dose but no model included both fentanyl dose and synergist dose). The interaction term (drug type $\times$ dose) was included when both variables were in the model, and the analyses were performed separately for each drug type when the interaction was significant. Body temperature and capture purpose (surgical vs. nonsurgical) were used as covariates in the full model for response variables 1 and 2. Handling time was used as a covariate for response variable 3, along with initial body temperature. Covariates for response variable 4 included handling time and postreversal holding time. Indicator variables coded as 1 or 0 were used to represent synergist type, antagonist type, and capture purpose in the model. Stepwise selection was used to reduce models, and the best-fit model was chosen based on Akaike information criterion (AIC) values (i.e., the best-fit model had the lowest AIC value). Linear regression analysis was used to examine the relationship between drug dose and induction time, and Fisher's exact test[25] was used to compare naloxone and naltrexone recycling rates. We used SAS statistical software (version 6.12, SAS Institute, Cary, North Carolina 27513, USA) for all analyses. Differences were considered significant at $\alpha = 0.05$.

RESULTS

From 1987 to 1997, 597 sea otters were anesthetized: 367 females weighing an average of 21.1 kg, and 230 males weighing an average of 25.6 kg. A total of 240 sea otters were anesthetized for surgical procedures, and 329 sea otters were anesthetized for nonsurgical biologic sampling (Table 1). An additional 28 sea otters were anesthetized for semen collection via electroejaculation, and because of the high level of stimulus involved, these animals were included in the surgical procedures category for analysis (Table 1). A total of 155 additional otters were captured but released without anesthetization because they did not fit the needs of the particular study at the time of capture. Sea otters handled during rescue efforts at the time of the 1989 *Exxon Valdez* oil spill[23] were not included in this study.

During these studies, there were six capture-related otter mortalities. Including the additional 155 sea otters captured but released without anesthetization, overall capture loss rate was 0.8%. Only one death (0.2% of anesthetized otters) was drug relat-

Table 1. Summary of drug dosages from a total of 597 anesthetized sea otters. Values are the mean (SD) dose (mg/kg) over time (including supplemental fentanyl dose and proportion of otters for which supplemental fentanyl was required), number and proportion of tremors or convulsions, and number and proportion of narcotic recycling events. Also presented are the grand mean (SD) and ranges for all surgical and nonsurgical anesthetizations.

		Fentanyl							% otters	
Year	*n*	Initial	Supplemental	% requiring supplemental	Azaperone	Diazepam	Naloxone	Naltrexone	Tremor or convulsion	Signs of recycling[a]
Surgical (mean handling time = 42 min)										
1987	25	0.33 (0.08)	0.14 (0.09)	32	0.24 (0.04)	0.00	0.54 (0.08)	0.00	64	ND[b]
1990[c]	28	0.27 (0.03)	0.08 (0.03)	25	0.26 (0.04)	0.00	0.52 (0.12)	0.00	36	44 (27)
1992	114	0.35 (0.07)	0.07 (0.03)	20	0.00	0.11 (0.03)	0.72 (0.15)	0.00	7	11 (99)
1992–1997	101	0.36 (0.09)	0.08 (0.04)	4	0.00	0.11 (0.02)	0.00	0.62 (0.18)	9	0 (16)[d]
Total	268	0.34 (0.08)	0.09 (0.05)	16	0.25 (0.04)	0.11 (0.03)	0.66 (0.16)	0.62 (0.18)	16	16 (142)
Range		0.19–0.60	0.19–0.60		0.16–0.33	0.07–0.22	0.34–1.10	0.33–1.80		
Nonsurgical (mean handling time = 28 min)										
1991	14	0.26 (0.04)	0.14 (0.02)	14	0.26 (0.06)	0.00	0.65 (0.21)	0.00	43	62 (13)
1991	16	0.19 (0.05)	0.12 (0.06)	19	0.18 (0.06)	0.05 (0.02)	0.60 (0.10)	0.00	13	27 (15)
1991–1992	93	0.22 (0.05)	0.08 (0.03)	9	0.00	0.08 (0.02)	0.47 (0.14)	0.00	5	13 (68)
1992–1997	206	0.23 (0.04)	0.12 (0.10)	9	0.00	0.08 (0.02)	0.00	0.43 (0.11)	8	0 (10)[d]
Total	329	0.23 (0.04)	0.11 (0.08)	10	0.22 (0.07)	0.08 (0.02)	0.51 (0.16)	0.43 (0.11)	9	20 (106)
Range		0.09–0.38	0.12–0.75		0.10–0.44	0.03–0.21	0.18–1.20	0.23–0.98		

[a] Percentage based on number of otters (in parentheses) monitored for recycling after antagonist injection.
[b] Animals were not monitored for recycling prior to 1990.
[c] Semen collection (i.e., high stimulus), not surgery.
[d] After no recycling observed with naltrexone use beginning in 1992, monitoring for recycling ended in 1993.

ed; it involved an animal compromised by injury prior to anesthesia.

Drug protocol

Early fentanyl/azaperone drug combination doses were near or at approximately a 1:1 ratio. In 1991, as supplies of azaperone become scarce, small amounts of diazepam were added to the fentanyl/azaperone combination. The fentanyl/diazepam combination replaced the fentanyl/azaperone combination at a 3:1 dose ratio near the end of 1991, and this combination has been used exclusively since 1992. The progression of drug doses and combinations used in this study is presented in Table 1. Supplemental fentanyl was required in 42 of 268 (~16%) surgical cases and 32 of 329 (~10%) nonsurgical biologic sampling cases. One female and one male never became adequately immobilized despite several injections totaling approximately 2.5 times the estimated required dose, and immobilization was reversed and the otters were released without further procedures. Additional diazepam was required for 15 animals (3% of fentanyl/diazepam anesthetizations) for control of seizures and tremors.

Mean (±SD) induction time was 9 (±4) min, and mean TFP was 15 (±4.5) min for the subset of 101 otters for whom both times were recorded. The difference of 6 min represents the average time needed to weigh, measure, and secure the otter for further procedures. For all other otters, mean TFP was essentially the same (14.5 ± 5 min, $n = 458$), indicating that this value could be used as an index of induction time. Variability in induction time and TFP was not explained by fentanyl or synergist dose (linear regression $R^2 < 0.03$ for all drugs). Induction times were similar for azaperone-anesthetized otters ($\bar{x} = 9.2$ min., SD = 5.1 min.) and diazepam-anesthetized otters ($\bar{x} = 8.9$ min., SD = 4.0 min; $t_{98} = 0.23$, $P = 0.8$).

As expected, low initial fentanyl dose led to a higher probability that supplemental fentanyl would be required, and these otters required more narcotic for surgical procedures (logistic regression, Wald $\chi^2 > 17$, $P < 0.001$; Fig. 1). Otters were just as likely to require supplemental fentanyl when it was initially used in combination with azaperone as when it was combined with diazepam (logistic regression, Wald $\chi^2 = 2.4$, $P = 0.12$).

Tremors or convulsions were observed during 72 of 597 (12%) anesthetic events. The probability of tremors or convulsions was lower for diazepam-anesthetized otters than for azaperone-anesthetized otters (logistic regression, Wald $\chi^2 = 3.5$, $P = 0.06$; Table 1). Forty-eight percent of otters immobilized with fentanyl/azaperone experienced tremors or convulsions versus only 7% for those immobilized with fentanyl/diazepam. Tremors were not significantly related to synergist dose or body temperature (logistic regression, Wald $\chi^2 < 0.5$, $P > 0.50$).

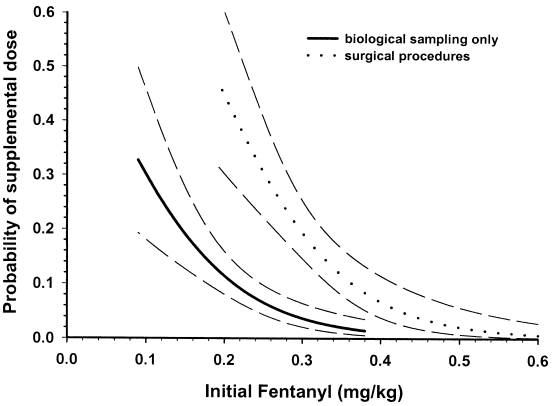

Figure 1. Probability that a sea otter will require supplemental fentanyl during processing in relation to the initial dose of fentanyl administered and the purpose of anesthesia (biologic sample collection only vs. surgical procedure).

Following antagonist injection, otters that became slow and unresponsive to human presence were interpreted to have experienced narcotic recycling. Some otters slowed to the point of losing righting ability and would briefly roll face down in the water. These otters were also unresponsive to human contact and could be easily handled for injection of additional antagonist. However, all signs of recycling were reversed with additional injections of antagonist, indicating the presence of true recycling rather than a sedative effect of residual azaperone or diazepam. Overall, 44 of 248 (18%) otters held at least 1 hr after antagonist injection showed signs of narcotic recycling, and all recycling events occurred when using naloxone as the antagonist. First signs of recycling usually occurred 1–2 hr after narcotic antagonism ($\bar{x} = 80$ min, range: 8–152 min). In these otters, the probability of recycling increased with fentanyl dose, but a marginally significant interaction between synergist type and fentanyl dose was found (Table 2). Without this interaction term, synergist type was highly significant. Thus, azaperone- and diazepam-anesthetized otters were analyzed separately (Table 2).

Twenty of 40 (50%) azaperone-anesthetized otters recycled, and the probability of recycling increased with the amount of fentanyl administered and decreased handling times (Table 2; Fig. 2). Four of 15 (27%) otters anesthetized with both azaperone and diazepam also showed signs of recy-

Table 2. Results of a logistic regression model of the probability of observing narcotic recycling in otters after administration of naloxone. Significant interaction in full model dictated separating diazepam- and azaperone-anesthetized otters.[a]

	Results of full model			Second best-fit full model		
	Wald χ^2	*P*	AIC[a]	Wald χ^2	*P*	AIC
Full model variables (X_i)						
Intercept	1.10	0.29	172.9	0.05	0.81	173.4
Fentanyl dose	3.71	0.05		3.61	0.06	
Synergist type	0.01	0.93		21.81	<0.0001	
Synergist type × fentanyl dose	2.13	0.14				
Handling time	7.26	0.007		6.31	0.01	
Holding time	3.45	0.06		3.76	0.05	
Diazepam only						
Intercept	2.04	0.15	126.4[b]			
Fentanyl dose	1.65	0.20				
Handling time	2.22	0.14				
Holding time	0.81	0.37				
Azaperone only						
Intercept				2.18	0.21	49.2[b]
Fentanyl dose				3.49	0.06	
Handling time				5.54	0.02	
Holding time				2.95	0.09	

[a] AIC = Akaike information criterion.
[b] Data from azaperone and diazepam anesthetizations separated, AIC values not comparable between models or with full model.

cling. In contrast, only 20 of 167 (12%) diazepam-anesthetized otters recycled, and in these otters recycling showed no significant relationship with fentanyl dose or handling time (Table 2). Thus, for azaperone-anesthetized otters, short handling times combined with high fentanyl doses (and subsequently high azaperone doses) increased the likelihood that an otter would recycle when antagonized with naloxone, but this relationship was not noted for diazepam-anesthetized otters.

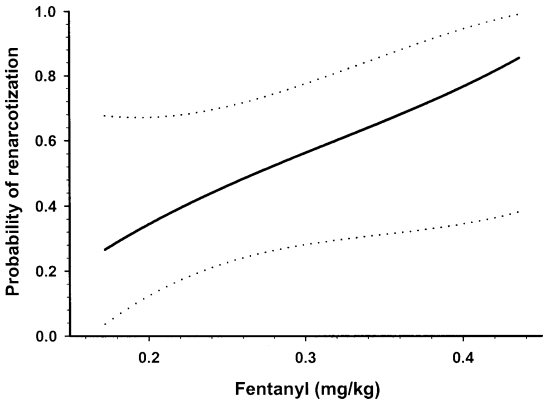

Figure 2. Probability of narcotic recycling for sea otters anesthetized with fentanyl and azaperone and reversed with naloxone.

Twenty-six otters were monitored after antagonism with naltrexone (maximum time = 3.3 hr). None showed any signs of recycling. Although statistical power is low because of small sample size, the result approached significance when compared with the recycling rate of naloxone antagonisms (Fisher's exact one-tailed test, $P = 0.06$ for otters held >1 hr).

Mean initial body temperature for all captured otters was 37.5°C (±0.9°C). During handling, body temperature generally increased with mean changes of +1.2°C and +1.6°C for nonsurgical biologic sampling and surgical procedures, respectively. Elevated temperatures occurred occasionally, even with close monitoring and efforts to keep the otters cool. Body temperature of 21 (3.5%) otters reached 40°C, at which point anesthesia was reversed immediately. There was no relationship between hyperthermia and fentanyl dose or synergist type (logistic regression, Wald $\chi^2 < 0.5$, $P > 0.39$), but the probability of hyperthermia increased with handling time and initial body temperature (logistic regression, Wald $\chi^2 > 4$, $P < 0.05$; Fig. 3).

Heart rates did not differ between azaperone- and diazepam-anesthetized otters and averaged approximately 135 beats/min ($t_{143} = 0.51$, $P > 0.50$; Table 3). Respiration rates appeared more depressed for diazepam-treated otters (15 ± 4 breaths/min) than

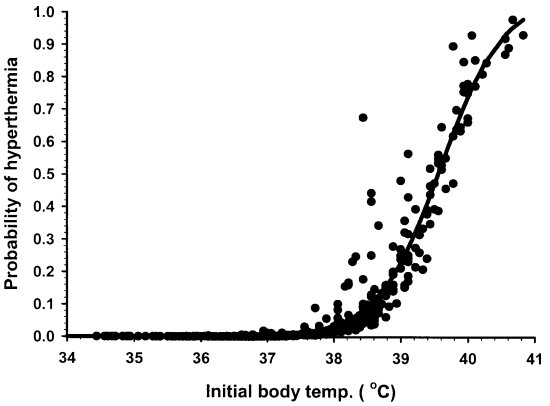

Figure 3. Probability of an anesthetized sea otter reaching a hyperthermic condition (>40°C) in relation to its initial body temperature at the time of induction.

for azaperone-treated otters (21 ± 4 breaths/min; $t_{98} = 5.88$, $P < 0.01$; Table 3), although color and capillary refill time never indicated problems with hypoxia. A pronounced sinus arrhythmia was often noted when recording respiration rate, but apnea was not noticeable.

DISCUSSION

The most recently published anesthesia protocol for sea otters[23] was developed from experience obtained handling sea otters captured for rehabilitation during the 1989 *Exxon Valdez* oil spill. In the early days after the spill, many otters were severely compromised by exposure to oil, and anesthesia was considered risky. Immobilizing these animals, when necessary, was accomplished with low doses of weak narcotics, such as meperidine hydrochloride in combination with diazepam. The general health and vigor of animals coming into the rehabilitation facilities increased with time, and more potent drugs were required. Fentanyl, in combination with diazepam (supplies of azaperone were limited), was most commonly used at initial dosages of about 0.1 mg/kg for both fentanyl and diazepam. However, because of prolonged procedures, supplemental doses up to a total of 0.8 mg/kg of fentanyl and 0.2 mg/kg of diazepam were sometimes required.[23] The combination of fentanyl, azaperone, and diazepam was also used, and the final recommendation of Sawyer and Williams[23] for the anesthetization of sea otters for up to 2.5 hr included 0.1 mg/kg of fentanyl and 0.5 mg/kg of azaperone in combination with 0.1–0.5 mg/kg of diazepam. As an alternative to azaperone, they advocated acepromazine at a dose of 0.05 mg/kg.

The protocol recommended by Sawyer and Williams[23] worked well in the clinical setting for sea otters needing to be cleaned, because washing and related handling sometimes continued for several hours. The use of the longer lasting, nonreversible neuroleptics (azaperone or acepromazine) significantly reduced the amount of supplemental narcotic required over these extended periods. But Sawyer and Williams[23] also pointed out that these same tranquilizers (particularly acepromazine) prolonged recovery times. However, sea otters in the rehabilitation centers could be antagonized and held in a controlled setting, allowing them to be closely monitored during recovery.

Sea otters captured for biologic sampling and measurement are generally handled immediately after capture and subjected to procedures lasting less than 1 hr. The initial reaction of a healthy, wild sea otter to capture includes a vigorous struggle. Animals in a highly excited state may require more drug for initial immobilization,[24] and initial underdosing can create significant problems.[11] Sea otters in our studies required higher doses of fentanyl than those recommended by Sawyer and Williams.[23] In addition, to reduce stress, immediate release was preferred rather than holding the animals after completion of procedures. Thus, the use of high doses of long-lasting neuroleptics is not advisable. Fentanyl in combination with diazepam alone at a ratio of 3:1 produced smooth inductions and provided anesthetic effects lasting at least 30–40 min. Diazepam is now reversible with flumazenil, but the residual diazepam may actually help reduce stress following release, and reversal of the diazepam did not appear necessary.

Table 3. Mean (SD) and ranges of heart rates and respiration rates recorded for sea otters anesthetized with fentanyl plus azaperone, azaperone and diazepam, or diazepam alone.

	Heart rate (beats/min)			Respiration rate (breaths/min)		
Synergist	*n*	Mean (SD)	Range	*n*	Mean (SD)	Range
Azaperone	35	133 (18)	108–177	19	21 (4)	16–28
Azaperone + diazepam	12	161 (18)	130–182	0		
Diazepam	110	135 (26)	76–212	81	15 (4)	8–35

Sea otters tolerated and sometimes required relatively high doses of fentanyl (one adult female required a dose of 0.75 mg/kg before she was adequately immobilized), but generally doses >0.36 mg/kg provided little benefit in terms of improved anesthesia. Less narcotic can be used when biologic sampling and tagging are the only purposes of capture. Electroejaculation procedures required doses somewhat higher than those used for obtaining other types of samples because of the intense physical stimulation.

Fentanyl is known to have excitatory central nervous system effects at times, resulting in tremor and seizures.[14] Diazepam has been used to control tremor and seizures in a variety of mammals,[11] including sea otters,[5,23] and it was found to be more effective than azaperone in the otters we handled.

Naloxone is an effective narcotic antagonist with a history of use in many species,[11] including sea otters.[27,28] However, it has a relatively short half-life,[7,21] and others using naloxone have reported recycling, although most often with more potent narcotics such as carfentanil.[12,13,16,22] For an animal such as the sea otter, which spends its life in the water, there is significant potential for narcotic recycling to cause fatalities. Sea otters experiencing the effects of recycling slowed to the point of resting quietly in the water and became unresponsive to human presence. With time, several animals began to roll face down in the water for at least several seconds. These otters were completely unresponsive to human contact, and at this point supplemental naloxone was given. Without intervention, the potential for drowning was clear. In 1989, one sea otter rehabilitated during the oil spill and subsequently anesthetized for a prerelease physical examination drowned in the recovery net pen when staff were distracted by members of the news media and other onlookers staging a protest (S. Rapp, pers. comm.). Presumably, this drowning occurred as a result of narcotic recycling. For fentanyl/azaperone-anesthetized sea otters antagonized with naloxone, the risk of recycling increased with increasing dose of fentanyl.

Naltrexone, like naloxone, is a pure antagonist. It has a longer half-life than naloxone in some but not all species[11,21] because its major metabolite is also active.[11,14] In general, naltrexone has been effective in preventing recycling,[4,12,13,18] often eliminating recycling completely.[1–3] No signs of recycling were observed in 26 fentanyl/diazepam-anesthetized otters up to 3 hr after naltrexone injection. Thus, in the sea otter the half-life of naltrexone appears to be longer than that of naloxone. Although use of naltrexone appeared to eliminate recycling in fentanyl/diazepam-anesthetized otters, no otters anesthetized with fentanyl/azaperone were treated with naltrexone; therefore, we do not know whether naltrexone would have prevented recycling in these animals.

Our recommended naltrexone dose of twice the fentanyl dose administered during processing (usually 0.44–0.66 mg/kg) is much higher than the 0.01 mg/kg recommended by Williams et al.[28] for naloxone. However, because naltrexone has no agonistic effect[11] and sea otters appear to tolerate relatively high doses, administration of extra naltrexone to prevent recycling seems prudent. Others have published similar recommendations.[1,13,16,18]

To our knowledge, no recycling-related mortalities occurred during our studies. However, prior to 1990, of the 45 radio-instrumented sea otters that were released immediately after reversal of anesthesia with naloxone, one disappeared and was not seen again. It is not known whether the disappearance of this otter was due to drowning after recycling of anesthesia, death from complications after surgery, radio failure, or movement of the otter out of the study area.

Generally, the body temperatures of the sea otters increased during handling, and careful temperature monitoring was critical to ensure the well-being of these otters throughout the handling procedure. Loss of temperature control is common under anesthesia, particularly for an animal such as the sea otter, which has a dense pelage with excellent insulating properties. Once an otter is removed from the water, its temperature can rise rapidly, depending primarily on environmental conditions. By keeping otters wet prior to sedation, either by holding them in a net pen or by running water over them when they are held in capture boxes, normal body temperatures can be maintained throughout the handling period.

Respiratory depression, apnea, and hypoxia are known physiologic effects of narcotics.[11,14] Compared with azaperone, diazepam decreased respiration rates. This effect may be due to the difference in pharmacologic characteristics between diazepam and azaperone. We do not know the normal respiration rate of a resting sea otter, although the means of 21 breaths/min for azaperone-anesthetized otters and 15 breaths/min for diazepam-anesthetized otters are within the range of normal for a dog of similar size.[17] We did not observe any signs of hypoxia in anesthetized sea otters based on gum color and capillary refill time; however, blood O_2 saturation levels were not measured. Ten sea otters in California anesthetized under the same drug protocol had an average of 79% and 92% blood O_2

saturation before and after masking with pure O_2, respectively (M. Murray, Monterey Bay Aquarium, pers. comm.). Diving mammals normally experience highly variable blood O_2 levels during submersion.[29] Sea otters, as diving mammals, may be tolerant of relatively low blood O_2 saturation levels.

Only one drug-related sea otter mortality occurred during these studies. In this instance, the sea otter had aspirated an unknown amount of seawater before anesthetization, which likely compromised its lungs. However, the extent of the injury was not known when the drugs were administered, and the otter appeared quite vigorous during handling. Overall, the capture and drug-related mortality rates for this study, at $<1\%$, appear to be well below what is often experienced when handling wild animals.

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