IMMOBILIZATION AND PHYSIOLOGICAL PARAMETERS ASSOCIATED WITH CHEMICAL RESTRAINT OF WILD PIGS WITH TELAZOL® AND XYLAZINE HYDROCHLORIDE

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ABSTRACT: We used a combination of Telazol® (3.3 mg/kg) and xylazine hydrochloride (1.6 mg/kg) to immobilize 144 wild pigs (*Sus scrofa*) with blow darts. This drug combination was safe and effective for rapidly immobilizing animals ranging in size from 34 to >170 kg and avoided difficulties associated with hand injections. For 123 single injection immobilizations, mean (±SD) induction times and effective handling periods averaged 5 (±2.5) and 52 (±18) min, respectively, and animals generally recovered for release within 120 min of initial injections. Animals that required two injections to immobilize ($n = 21$) received lower initial doses of Telazol® and xylazine hydrochloride than those immobilized with a single injection because of errors in estimating body sizes; we found that there was a threshold dose required to immobilize wild pigs from 2.8 to 3.3 mg/kg Telazol® and 1.4 to 1.6 mg/kg xylazine. Although neither age or sex influenced immobilization parameters, animals in good condition required longer to recover than those in poor condition. However, animals immobilized with two injections recovered as rapidly as those immobilized with a single injection. Heart rates and body temperatures declined slightly during the immobilization period, but respiration rates and blood oxygen saturation levels remained stable. In general, single injection immobilizations were preferable because they minimized problems associated with injecting partially immobilized animals. Because it was difficult to accurately estimate the sizes of large wild pigs (≥90 kg), and because wild pigs that were partially immobilized were difficult to handle, we recommend increasing the drug doses to 4 mg/kg Telazol® and 2 mg/kg xylazine hydrochloride when injecting relatively large animals to assure single injection immobilizations. Although recovery periods may be prolonged, higher doses of Telazol® and xylazine should be safe based on data from domestic pigs.

Key words: *Sus scrofa*, wild pigs, Telazol®, xylazine hydrochloride, arterial oxygen concentrations, body condition, immobilization.

INTRODUCTION

Wild pigs (*Sus scrofa*) are often trapped and immobilized as part of ecological studies (Baber and Coblentz, 1986). Baber and Coblentz (1982) immobilized wild pigs that ranged in size from 9 to 60 kg on Santa Catalina Island, California (USA), using ketamine hydrochloride (HCL) and xylazine HCL. However, during research on wild pigs in mainland California where adult animals (>18 mo) are usually larger than 60 kg (mean ± SD = 71 ± 14 kg and 91 ± 35 kg for females and males, respectively; this study), we found that the ketamine HCL and xylazine HCL drug combination did not effectively immobilize animals >50 kg. Also, the large volume of

drugs needed to immobilize wild pigs at Baber and Coblentz's doses (15 to 20 mg/kg ketamine and 15 to 20 mg/kg xylazine) generally required injecting animals by hand. Physically restraining large wild pigs in traps is both difficult and dangerous and may cause undue physiological stress to the animals (Sweitzer et al., 1997). Thus, it would be useful to develop a drug combination for immobilization of wild pigs of all sizes without the use of hand injections.

Telazol® (Fort Dodge Laboratories Inc. Fort Dodge, Iowa, USA) is a 1:1 mixture of tiletamine HCL and zolazepam HCL which can be reconstituted to high potency (≥200 mg/ml) for small volume doses

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in projectile darts (Schobert, 1987). Tiletamine HCL is an injectable anesthetic agent chemically related to, but more potent than, ketamine; zolazepam HCL is a benzodiazepine tranquilizer similar to diazepam (Thurmon et al., 1988). Xylazine HCL is a sedative and analgesic with muscle relaxant properties (Plumb, 1991) which is often used in combination with ketamine and Telazol® to immobilize numerous wild and domestic animals.

Telazol®, and the combination of Telazol® and xylazine have been used to successfully immobilize numerous species of wildlife including polar bears (*Ursus maritimus*; Stirling et al., 1989), giant Chacoan peccaries (*Catagonus wagneri*; Allen, 1992a), red howler monkeys (*Alouatta seniculus*; Agoramoorthy and Rudran, 1994), porcupines (*Erethizon dorsatum*; Hale et al., 1994), Rocky Mountain elk (*Cervus elaphus nelsoni*; Millspaugh et al., 1995), and Ethiopian wolves (*Canis simensis*; Sillero-Zubiri, 1996). Although Telazol® alone is an effective immobilizing agent for many species (Gray et al., 1974; Schobert, 1987; but see Loughlin and Spraker, 1989), Telazol® in combination with xylazine was superior to Telazol® alone for immobilizing domestic pigs (Ko et al., 1993). In this paper we describe immobilization and physiological parameters associated with chemical restraint of wild pigs with Telazol® and xylazine.

MATERIALS AND METHODS

Wild pigs were trapped and immobilized as part of research on wild pig populations in the coastal region of central and northern California (35°23′ to 39°23′N, 120°51′ to 123°22′W) in the summers of 1994 and 1995. Wild pigs were baited with fermented corn and trapped in modified panel traps as described by Sweitzer et al. (1997). Because wild pigs can overheat and die when exposed to warm ambient temperatures (Baber and Coblentz, 1986), traps were set at dusk and checked to begin processing animals 1 to 2 hr before dawn or late at night. Burlap was draped around the outside of the traps to help calm the animals prior to immobilizations. Multiple wild pigs were often captured and animals were generally immobilized and processed one at a time from the larg-

est to the smallest (wild pigs <12 kg were not immobilized). Following sedation, wild pigs were removed from traps, hobbled with nylon or leather straps, and blindfolded after application of a mild ophthalmic ointment (Pharmaderm, Melville, New York, USA) to the eyes. Data collected during processing included dental formulas for aging animals as subadults (≤18 months) or adults (>18 months) (Matschke, 1967), mid-sternal chest circumference, mid-dorsal body length from the base of the skull to the top of the tail, and body weight (±1 kg). Ambient temperatures during processing ranged from 4 C to 37 C and the body temperatures of immobilized wild pigs were monitored and animals were cooled by spraying with water if body temperatures increased to above 40 C.

We first immobilized six wild pigs using approximately 15 mg/kg ketamine and 3 mg/kg xylazine but with unsatisfactory results; heart rates, respiratory rates, and body temperatures were elevated and animals recovered poorly from immobilizations (Sweitzer et al., 1997). After further trials we found that doses of about 3.3 mg/kg Telazol® and about 1.7 mg/kg xylazine appeared to be effective and used these doses thereafter. Initial doses were based on estimated body weights with precise doses calculated retrospectively after weighing.

To immobilize wild pigs <90 kg a solution of 100 mg/ml Telazol® and 50 mg/ml xylazine HCL was used; the 500 mg vial of Telazol® was reconstituted with 2.5 ml of sterile water and 2.5 ml of 100 mg/ml xylazine. To immobilize wild pigs >90 kg a solution of 200 mg/ml Telazol® and 100 mg/ml xylazine was used; the 500 mg vial of Telazol® was reconstituted with 2.5 ml of 100 mg/ml xylazine. With the two different concentrations a total volume of <3 ml of drugs was used to immobilize animals as large as 180 kg. Animals were darted in the hind quarters or neck with 3 ml Telinject blow darts (Telinject USA, Saugus, California) propelled through a 1.2 m blow pipe.

Heart rates, respiratory rates, and rectal body temperatures were monitored during immobilizations. Heart rates were monitored using a stethoscope, respiration rates were determined by visual inspection, and rectal temperatures were measured using a digital thermometer. Whenever possible, physiological parameters were measured four times beginning when immobilized animals were first removed from traps, usually ≤10 min post-injection, and at three 12 to 15 min intervals thereafter. In some cases wild pigs began to recover from the effects of drugs and struggled near the completion of processing. Because struggling influenced physiologic parameters, data for animals

that struggled were excluded. Data on heart rates, respiration rates, and body temperature were grouped into two time categories for analyses; early (<30 min post injection) and late (≥30 min post injection) in the immobilization period. If more than one set of measurements was available for an individual within a time category, the data were averaged into one measure for analyses. Eleven single and 66 multiple measures occurred in the early period, whereas 19 single and 58 multiple measures occurred in the late period.

In 1995 the blood oxygen saturation of immobilized wild pigs was measured at 30 and 45 min post injection with a pulse oximeter (N-10 Pulse Oximeter, Nellcor Inc., Hayward, California). Oxygen saturation readings were taken by holding the animal's mouth open and attaching a clip sensor to a cleaned site on the end of the tongue. Four oxygen saturation readings over a 2-min period were averaged into a single measure for analyses. Heart rates from the pulse oximeter were nearly identical to those determined using a stethoscope; thus, we believe that the pulse oximeter readings were valid. However, the blood oxygen saturations of animals that struggled were not measured because it was difficult to attach the sensor to the tongue, and readings from struggling animals were variable. Blood oxygen analyses were restricted to animals with data for both the 30- and 45-min time periods because trends in oxygen saturation over time were of greater biological interest than single point-in-time values (Allen, 1992b).

Immobilization periods were timed with a digital stopwatch from the initial injection until animals were able to stand and walk without falling. Data were collected on time to sternal recumbency (laying upright on chest), time to induction (unconscious or unresponsive to gentle prodding), time to responsive/arousal (respond or withdraw from auditory or tactile stimulus), recovery to sternal recumbency (laying upright on chest), and recovery to ambulatory (stand and walk without falling). We also calculated the effective handling period as the time from induction when it was safe to approach and handle immobilized pigs to when animals were responsive to auditory or tactile stimulus and began to struggle during processing. In general, upon completion of processing animals were returned to traps, unhobbled, and observed during recoveries. Animals were released when they were able to walk or run in a coordinated manner, usually 10 to 15 min after recovering to ambulatory. Due to logistical considerations, however, the recovery of every animal was not observed and sample sizes varied between the initial immobilization data and the recovery data.

Most (n = 123) animals were immobilized with a single dose of Telazol® and xylazine; however, 29 animals required two or more doses for immobilization either because the first dose was not sufficiently effective (n = 22), or they received partial injections (n = 7). Data for wild pigs that received one injection were analyzed separately from those that received additional injections. Wild pigs that received incomplete injections or those that received more than two doses (n = 8) were excluded from analyses because it was not possible to determine the exact doses they received.

An index of body condition in wild pigs was derived to evaluate whether immobilizations were influenced by body condition. The condition index was based on the residuals from the regression of the natural log of body weight on the natural log of body volume. Volumes of individuals were estimated by considering the pig body shape as a cylinder. Estimated volumes were computed by a standard equation: $V = \pi r^2 h$ where r = mid-sternal chest circumference in cm/2π and h = body length in cm. The residuals from the regression equation (LN(body weight) = −5.04 + 0.91LN(body volume), adj. R^2 = 0.99, P < 0.001, n = 195) were used to group animals into good (positive residuals) or poor (negative residuals) condition; animals with positive residuals can be considered to be in relatively good condition compared to animals with negative residuals (Berger and Peacock, 1988). The sample size for this regression was larger than the number of immobilizations reported because the condition analysis included all animals measured during processing, including small animals that were not immobilized, those that were immobilized with ketamine and xylazine, and animals that received partial injections.

Independent sample t-tests were used to compare drug doses and immobilization parameters between single and double injection immobilizations, and physiological data between subadults and adults (Ko et al., 1993). Paired sample t-tests were used to compare heart rates, respiratory rates, rectal body temperatures between early and late in immobilizations, as well as blood oxygen saturation levels at 30 and 45 min post injection (Sokal and Rohlf, 1981). Analysis of covariance (ANCOVA) was used to analyze times to sternal recumbency, induction, arousal, recovery to sternal recumbency, and ambulatory times among the different age, sex and body condition categories following Agoramoorthy and Rudran (1994). Body weight and Telazol®/xylazine dose levels were used as covariates in the model to control

for the effects of these variables on immobilization parameters (Sokal and Rohlf, 1981). Times to sternal and induction were not normally distributed and these variables were log transformed prior to analyses. Linear regression was used to examine the relationship between actual and estimated body weights and G-tests were used for all categorical comparisons (Sokal and Rohlf, 1981). Statistical software program SYSTAT (Wilkinson, 1990) was used for all analyses and data are presented as means ±1 SD.

RESULTS

Wild pigs that received single injections of Telazol® and xylazine were immobilized to induction within 5 min (range = 2 to 16 min), effective handling periods were about 53 min (range = 18 to 100 min), and they recovered to ambulatory in 96 min (range = 45 to 240 min) (Table 1). There were no differences with respect to age or sex in the doses of Telazol® and xylazine used for single injection immobilizations (age comparison Telazol® dose $t = -1.8$, df = 121, $P = 0.10$; age comparison xylazine dose $t = -1.57$, df = 121, $P = 0.12$; sex comparison Telazol® dose $t = 0.23$, df = 121, $P = 0.82$; sex comparison xylazine dose $t = 0.5$, df = 121, $P = 0.63$). Also, there were no differences in the adjusted means for time to sternal recumbency, induction, responsive/arousal, recovery to sternal recumbency, recovery to ambulatory, or effective handling period with respect to age or sex when Telazol®/xylazine dose and body weight were used as covariates in ANCOVA models ($P > 0.10$). However, animals in good condition became responsive and recovered to sternal recumbency and ambulatory later than those in poor condition (ANCOVA model for time to responsive/arousal with Telazol®/xylazine dose and body weight as covariates body condition $F = 4.65$, df = 1,83, $P = 0.03$; ANCOVA model for recovery to sternal recumbency body condition $F = 5.05$, df = 1,75, $P = 0.03$; ANCOVA model for recovery to ambulatory body condition $F = 4.13$, df = 1,72, $P = 0.05$). For animals in good condition, the mean times to responsive/arousal, recovery to sternal re-

cumbency, and recovery to ambulatory were 57.5 ± 16.0 min, 79.5 ± 21.9 min, and 100.0 ± 33.4 min, respectively, whereas the mean times to responsive/arousal, recovery to sternal recumbency, and recovery to ambulatory for animals in poor condition were 49.2 ± 17.2, 69.9 ± 22.4 and 90.1 ± 22.1 min, respectively. There were no significant interactions for the immobilization parameters among animals with respect to age, sex, or body condition with Telazol®/xylazine dose and body weight as covariates in ANCOVA models ($P > 0.05$).

Wild pigs that received two injections of Telazol® and xylazine were immobilized to induction within 18 min (range = 3 to 30 min), effective handling periods were about 55 min (range = 8 to 120 min), and they recovered to ambulatory in 107 min (range = 50 to 191 min) (Table 1). Although wild pigs that were injected twice received higher doses and took longer to immobilize than those immobilized with single injections (Table 1) (Telazol® dose $t = -3.3$, df = 142, $P = 0.001$; xylazine dose $t = -3.1$, df = 142, $P = 0.003$; ANCOVA model for time to induction with Telazol®/xylazine dose and body weight as covariates injection number $F = 29.7$, df = 1, 130, $P < 0.001$), they were similar to those receiving single injections in their times for responsive/arousal, recovery to sternal recumbency, recovery to ambulatory, and effective handling period (ANCOVA models with Telazol®/xylazine dose and body weight as covariates, $P > 0.11$). Also, adults were more likely to require additional injections than subadults ($G = 13.05$, df = 1, $P < 0.001$), potentially because it was more difficult to process adults that were partially immobilized than subadults that were partially immobilized (adult males were no more likely to require additional injections than were adult females; $G = 1.7$, df = 1, $P = 0.19$).

Variation in initial doses due to inaccurate weight estimates influenced the number of injections needed to immobilize animals. Based on the regression relationship

between actual weights (AWT) and estimated weights (EWT), we inferred that we were fairly accurate at estimating body weights (AWT = 0.97+1.00*EWT, adj. R^2 = 0.94, df = 1,144, $P < 0.001$); however, on further analysis, the weights of animals requiring two injections to immobilize were underestimated more often than those injected a single time ($G = 5.2$, df = 1, $P = 0.02$). The initial doses received by animals immobilized with two injections (2.88 mg/kg Telazol® and 1.44 mg/kg xylazine) were lower than the doses received by animals immobilized with single injections (Table 1, t-tests, $P < 0.001$). Based on these data, there was a threshold dose of Telazol® and xylazine needed to immobilize wild pigs in the range between 2.88 mg/kg Telazol® and 1.44 mg/kg xylazine and 3.23 mg/kg Telazol® and 1.63 mg/kg xylazine.

On initial analysis, heart rates, body temperatures, respiratory rates, and blood oxygen saturation levels were higher for subadults than for adults (age comparisons heart rate $t = 3.98$, df = 75, $P < 0.001$, body temperature $t = 4.20$, df = 75, $P < 0.001$; respiratory rate $t = 3.58$, df = 75, $P = 0.001$; oxygen saturation $t = 2.30$, df = 42, $P = 0.03$); thus, data for the two age classes were analyzed separately. Among subadults, heart rates and body temperatures were higher early in processing (<30 min post injection) compared to later in processing (≥30 min post injection) (heart rate paired $t = 6.5$, df = 37, $P < 0.001$; body temperature paired $t = 5.9$, df = 37, $P < 0.001$). Mean heart rates and body temperatures among subadults early in processing were 88.1 ± 20.6 and 39.2 ± 0.6, respectively, whereas heart rates and body temperatures late in processing were 75.8 ± 16.5 and 38.6 ± 0.9 C, respectively. Respiratory rates and oxygen saturations among subadults were similar early and late in processing (respiratory rate paired $t = 0.94$, df = 37, $P = 0.35$, oxygen saturation paired $t = -0.84$, df = 21, $P = 0.4$), averaging 31.6 ± 7.5 ($n = 38$) and 94.3 ± 1.8 ($n = 22$), respectively.

Among adults, heart rates and body temperatures were also higher early in processing compared to later in processing (heart rate paired $t = 2.2$, df = 38, $P < 0.03$; body temperature paired $t = 4.8$, df = 38, $P < 0.001$). Heart rates and body temperatures early in processing were 71.6 ± 15.4 and 38.4 ± 1.0, respectively, whereas heart rates and body temperatures late in processing were 67.5 ± 14.5 and 37.8 ± 1.4 C ($n = 39$), respectively. Respiratory rates and oxygen saturations among adults were similar early and late in processing (respiratory rate paired $t = 0.005$, df = 38, $P = 0.9$; oxygen saturation paired $t = 1.3$, df = 19, $P = 0.22$); averaging 24.8 ± 7.7 ($n = 39$) and 93.1 ± 1.8 ($n = 20$), respectively.

DISCUSSION

In this study the combination of Telazol® (about 3.2 mg/kg) and xylazine (about 1.6 mg/kg) was effective and safe for immobilizing wild pigs that weighed from 16 to >170 kg. When animals were appropriately dosed, inductions were rapid, effective handling periods were sufficient for careful and thorough processing, recoveries proceeded smoothly (little struggling or kicking), and animals generally recovered to a releasable state (controlled walking) within 2 hr of initial injections. Also, no mortalities occurred during processing and most of the immobilized animals were subsequently observed in photographs from automatic camera stations used in our population research (Sweitzer et al., 1996). Further, by varying the concentration of Telazol® it was possible to immobilize animals >170 kg using blow darts. This was important because by avoiding physically restraining animals for hand injections, we minimized capture-related stress, which can seriously impair the health of animals (Spraker, 1993; Beringer et al., 1996).

Body condition was the only variable evaluated that was significantly related to the immobilization parameters. The observation that wild pigs in good condition re-

covered from the effects of drugs more slowly than those in poor condition is consistent with the clinical observation that relatively fat animals metabolize drugs at a slower rate than lean animals (Lumb and Jones, 1996). Another potential source of variation in recovery times was differences in drug doses among animals (Table 1). Also, it may have been possible to shorten the recovery periods in immobilized wild pigs by administering a reversal agent like yohimbine HCL.

Although most double injection immobilizations were successful, single injection immobilizations were preferable because they minimized problems associated with handling partially immobilized wild pigs such as increases in body temperature, respiratory rate, heart rate, and difficult recoveries (Sweitzer et al., 1997). Single injection immobilization success was enhanced by accurately estimating body weights to determine the appropriate initial drug dose. This was important because there appeared to be a threshold dose around 2.8 to 3.3 mg/kg Telazol® and 1.4 to 1.6 mg/kg xylazine required to effectively immobilize wild pigs. In this field study, we used a relatively low dose of Telazol® and xylazine that was close to this threshold in order to minimize the time between injection and release. In the summer in western California, ambient temperatures rapidly increase after sunrise and it was important to avoid lengthy recoveries so that animals recovering in traps did not overheat. In other situations, potentially longer recoveries associated with higher doses may not be as critical to animal safety. Also, because it is more difficult to estimate weights of large wild pigs (>90 kg), we recommend erring toward heavier weight estimates when immobilizing large animals. In domestic pigs, drug doses of up to 4.4 to 6.0 mg/kg Telazol® and 1.1 to 2.2 mg/kg xylazine were not harmful (Ko et al., 1993; Thurmon et al., 1988).

Based on circumstantial evidence from one of two double injection failures, we

TABLE 1. Immobilization parameters from wild pigs using Telazol® and xylazine HCL from California in 1994 and 1995.

Injection type	Telazol® (mg/kg)	Xylazine (mg/kg)	Time from injection (min) to:					Effective handling period (min)
			Sternal	Induction	Responsive or arousal	Recover to sternal	Recover to ambulatory	
Single	3.24 ± 0.46[a] (123)[b]	1.63 ± 0.23 (123)	2.6 ± 1.2 (120)	5.0 ± 2.5 (118)	54.8 ± 17.8 (102)	76.0 ± 22.8 (90)	96.4 ± 31.0 (86)	52.2 ± 17.7 (102)
Double	3.63 ± 0.65 (21)	1.82 ± 0.32 (21)	4.8 ± 2.6 (20)	18.2 ± 7.9 (18)	58.7 ± 17.8 (17)	89.6 ± 21.1 (17)	106.8 ± 31.2 (17)	54.6 ± 27.4 (16)

a Mean ± SD.
b Sample size.

believe that success at immobilizing animals with two injections was contingent on minimizing the period between the first and second injections. When attempting to immobilize one animal that was initially under dosed, there was a relatively long 25-min interval between the first and second injection due to difficulty separating the partially immobilized animal from two other wild pigs in the trap. The relatively long 25 min delay between the first and second dose may have contributed to the failure of the immobilization because the initial dose may have been partly metabolized; in 21 successful two-dose immobilizations, the mean delay between injections was 16.7 ± 4.4 min (range = 9.8 to 25 min).

Physiologically, the small decreases in heart rate and body temperatures (Table 2) were consistent with the onset and maintenance of anesthesia. In immobilization trials on domestic pigs using Telazol® and xylazine, both Thurmon et al. (1988) and Ko et al. (1993) noted decreases in heart rates and body temperatures during processing. Although these workers also noted decreases in respiratory rates, in our study respiratory rates remained constant, as did blood oxygen saturations. Allen (1992a) reported that an average oxygen saturation of 93.2% in Chacoan peccaries (*Catagonus wagneri*) immobilized with Telazol® was consistent with a healthy physiological state. This value was similar to the average oxygen saturation of 94% determined for wild pigs immobilized with Telazol® and xylazine in our study. Although the pulse oximeter-derived oxygen saturations in wild pigs were not validated in this study, this non-invasive technique is valuable because it can provide continuous monitoring of oxygen saturation trends during anesthesia (Allen, 1992b).

We conclude that the Telazol® and xylazine drug combination was effective and safe for immobilizing trapped wild pigs. At doses of about 3.3 mg/kg Telazol® and about 1.65 mg/kg xylazine, induction times, effective handling periods, and recovery to ambulatory were about 5, 53, and 96 min, respectively. Also, it should be safe to administer higher doses of Telazol® (4–6 mg/kg) and xylazine (≥2 mg/kg) to ensure single injection immobilizations.

ACKNOWLEDGMENTS

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