CHEMICAL IMMOBILIZATION OF FREE-RANGING MOOSE

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ABSTRACT: A wide range of drugs and drug combinations have been used to capture free-ranging moose (*Alces alces*). Currently, potent opioids are considered the drugs of choice for capture of free-ranging moose. Recommended doses are carfentanil at 0.01 mg/kg or etorphine at 7.5 mg/adult. Combining an opioid with a sedative drug like xylazine will increase the risk of bloat, regurgitation, and aspiration of rumen contents. Extreme toxicity for humans and lost darts are major concerns when using potent opioids under field conditions. The best non-opioid alternative is medetomidine at 40-50 mg/adult combined with ketamine at 600 mg/adult. Carfentanil, etorphine, and medetomidine-ketamine have wide safety margins in moose and the risk of severe anesthetic side effects in healthy animals is minimal. Chemical immobilization from a helicopter in winter is considered the best capture method for moose. Due to animal welfare considerations and a low therapeutic index, neuromuscular blocking agents should not be used in moose. A mortality rate greater than 2% during immobilization and a one month post capture period is not acceptable for routine moose captures.

ALCES VOL. 39: 243-253 (2003)

Key words: *Alces alces*, anesthesia, capture, carfentanil, etorphine, immobilization, ketamine, medetomidine, xylazine

Free-ranging moose (*Alces alces*) are chemically immobilized for various research and management purposes: radiotransmitter deployment, collection of biological materials, morphometry, health examination, and translocation. Most moose are approached with a helicopter or occasionally by snowmobile, all-terrain vehicle, car, boat, or on foot, and drugs are administered by projectile darts fired from a dart gun. The first chemical immobilization of free-ranging moose was carried out in Alaska in 1957-58 with nicotine, a neuromuscular blocking (NMB) agent (Rausch and Ritcey 1961). Since then a wide range of drugs and drug combinations have been used to capture free-ranging moose in North America and Europe, including other NMB agents, tranquilizers, sedatives, and anesthetics. Franzmann (1982, 1998) has published excellent reviews of moose chemical immobilization. Here we present an update on recommended drugs, doses, and methods for chemical capture of free-ranging moose.

CHEMICAL CAPTURE VERSUS NET-GUNNING

Although helicopter net-gunning has been successfully used on moose, with an immediate capture mortality rate of less than 1% (Carpenter and Innes 1995), mortality rates as high as 14% have been reported from other projects using this method (Olterman et al. 1994). There is no doubt that helicopter net-gunning is a useful method for capture of free-ranging ungulates, and in some species it is even considered to be better than chemical immobilization (Kock et al. 1987a,b,c). In moose, however, we are not aware of a single

publication on stress physiology or possible long-term negative effects (e.g., exertional myopathy, increased risk of predation, reduced calving success, and reduced survival of offspring) after capture by helicopter net-gunning. Whether net-gunning is an acceptable method for moose capture remains to be documented.

IMMOBILIZING DRUGS

There are three major groups of drugs currently used for wildlife capture: Alpha-2 adrenoceptor agonists, opioid agonists, and cyclohexanes (Kreeger et al. 2002). The NMB agents are a fourth group that was extensively used during the pioneer days of chemical immobilization. NMB drugs cause muscular paralysis but the animal is conscious, aware of its surroundings and fully sensory, and can feel pain and experience psychogenic stress. Due to a very narrow range between effective immobilizing doses and lethal doses, mortality rates as high as 70% have occurred with NMB agents (Kreeger et al. 2002). Although inferior to modern immobilizing drugs, the NMB agent succinylcholine has been used for moose capture in recent years (Delvaux et al. 1999). However, the reported mortality rate due to respiratory paralysis was 7% and only 63% of the immobilization attempts were successful. Due to animal welfare considerations and the low therapeutic index (effective dose:lethal dose), succinylcholine or other NMB agents should not be used for moose immobilization.

Alpha-2 adrenoceptor agonists include xylazine, romifidine, detomidine, and medetomidine. These agents induce dose-dependent sedation and analgesia and they have anxiolytic and muscle relaxing properties. The difference in potency between the alpha-2 agonists is species dependent, but no controlled studies have been done in moose or other wildlife species. In sheep, the equipotent sedative doses (mg/kg) for xylazine, romifidine, detomidine, and medetomidine are 0.15, 0.05, 0.03, and 0.01, respectively (Kreeger et al. 2002). Although these drugs may induce deep sedation and immobilization in large doses, sudden arousal may occur. In highly excited animals, induction times are usually prolonged and immobilization may be impossible regardless of the dose administered. Alpha-2 agonists should therefore never be used as the sole agent for capture of free-ranging moose. They are, however, very useful in combination with opioids or cyclohexanes. Alpha-2 agonists have the ability to potentiate other CNS-drugs; e.g., if ketamine is combined with medetomidine the effective anesthetic dose of ketamine is reduced by as much as 75% in some species (Jalanka and Roken 1990). The effects of alpha-2 agonists can be rapidly and permanently reversed by atipamezole, a potent and specific alpha-2 adrenoceptor antagonist (Kreeger et al. 2002). Other less specific reversal agents, such as yohimbine and tolazoline, can be used to antagonize xylazine, the least potent of the alpha-2 agonists.

Opioid agonists used for wildlife immobilization include carfentanil, etorphine, fentanyl, and, to some extent, thiafentanil and sufentanil (Kreeger et al. 2002). In moose and other cervids, carfentanil (North America) and etorphine (Europe) have been the primary opioids, either alone or in combination with xylazine (Kreeger et al. 2002). Carfentanil and etorphine both have high therapeutic indices in moose; i.e., the same dose can be used in most adults regardless of body weight. Underdosing with opioids may cause excitement and hyperthermia and overdosing is therefore considered to be better than underdosing. Although not a "new" agent for wildlife captures (Stanley et al. 1988, 1989), thiafentanil (formerly identified as A-3080) is still an investigational drug for wild animal capture (Citino et al.

2001, Grobler et al. 2001, Kreeger et al. 2001, Citino et al. 2002). The relative potencies of carfentanil, etorphine, and thiafentanil in moose are approximately 2:1:1 (McJames et al. 1994, Kreeger et al. 2002). The effects of opioids can be reversed by several opioid antagonists. Naltrexone is the preferred agent due to its potency and long duration (i.e., less risk of renarcotization). Other opioid antagonists include naloxone, nalmefene, nalbuphine, and diprenorphine.

Cyclohexanes (also known as NMDA antagonists) include ketamine and tiletamine. These drugs are general anesthetics; i.e., they induce unconsciousness and amnesia. However, due to severe side effects like muscle rigidity, frequent convulsions, and rough recoveries, these agents should only be used in combination with an alpha-2 agonist or another tranquilizing or sedative drug (Kreeger et al. 2002). The relative potency between tiletamine and ketamine is approximately 2.5:1 and the duration of action of tiletamine is about three times longer than with ketamine. Tiletamine is not available as a single product and is marketed in a 1:1 combination with the benzodiazepine agonist zolazepam. There is no reversal agent to the cyclohexane drugs. Too early administration of an alpha-2 antagonist in animals immobilized with an alpha-2 agonist in combination with ketamine or tiletamine, may uncover residual side effects of the cyclohexane component and can cause uncontrolled recoveries, hyperthermia, trauma, and even death (Kreeger et al. 2002).

In general, antagonists should be administered intramuscularly. Intravenous injection of the reversal agent will cause complete recovery in less than one minute in animals immobilized with opioids alone. Such rapid recoveries may be stressful to the animals and may jeopardize the safety of both animals and people. Intravenous administration of reversal agents should therefore only be considered in an emergency situation.

Carfentanil

A large number of free-ranging moose have been immobilized with either carfentanil alone or carfentanil combined with xylazine (Franzmann 1982, 1998; Roffe et al. 2001; Kreeger et al. 2002). Recommended doses of carfentanil alone are 0.01 mg/kg or 3-6 mg/adult. Carfentanil is marketed as a 3 mg/ml solution (Wildnil®, Wildlife Pharmaceuticals Inc., Ft. Collins, Colorado, USA) and the dose for an adult moose will fit into a standard dart of most remote drug delivery systems. For reversal, naltrexone at 100 mg per mg carfentanil should be administered (Kreeger et al. 2002).

In several studies carfentanil at 3-4 mg/adult has been used in combination with xylazine (e.g., Cervizine® 10 mg/ml, Wildlife Pharmaceuticals Inc.) at 25-175 mg/adult to improve muscle relaxation and to potentiate the effect of carfentanil so that the opioid part of the combination can be reduced. However, moose immobilized with carfentanil-xylazine are usually not able to support sternal recumbency and may be more susceptible to aspiration pneumonia (Kreeger 2000). Unless there are overriding considerations, the addition of xylazine to opioids in moose is not recommended (Kreeger et al. 2002). If carfentanil is combined with xylazine, the effects of xylazine should be antagonized by either atipamezole (Antisedan® 5 mg/ml, Orion Pharma Animal Health, Turku, Finland) at 1 mg per 10 mg xylazine, yohimbine (Antagonil® 5 mg/ml, Wildlife Pharmaceuticals Inc.) at 1 mg per mg xylazine, or tolazoline (Tolazoline® 100 mg/ml, Lloyd Laboratories, Shenandoa, Iowa, USA) at 15 mg per mg xylazine (Roffe et al. 2001, Kreeger et al. 2002, Plumb 2002).

Etorphine

Etorphine, alone or in combination with xylazine, has been the drug of choice for moose capture in Scandinavia (Sandegren et al. 1987, Arnemo et al. 2001). Standard doses are 7.5 mg etorphine/adult (Etorphine HCl® 9.8 mg/ml, Vericore Veterinary Products, Novartis Animal Health UK Ltd., Litlington, UK) or 2.25 mg etorphine + 10 mg acepromazine/adult (Large Animal Immobilon® 2.25 mg/ml, Vericore Veterinary Products, Novartis Animal Health UK Ltd.) combined with 100 mg xylazine/adult (Rompun® Dry Substance, Bayer AG, Leverkusen, Germany). These doses fit into a standard dart of most remote drug delivery systems. Data from 1,464 immobilizations carried out over a 19-year period in Norway (Arnemo et al. 2001; J. M. Arnemo, unpublished data) show that ethorphine alone is an extremely safe and effective drug in moose and there is no indication for combining etorphine with an alpha-2 agonist. Due to the potentiating effect and muscle relaxing properties of alpha-2 agonists, moose immobilized with etorphine-xylazine or etorphine-medetomidine are usually not able to maintain sternal recumency and regurgitation of rumen contents are frequently seen (J. M. Arnemo, unpublished data). Diprenorphine is a specific antagonist for etorphine and is marketed in the same package as etorphine at a concentration of 1.2 times the concentration of etorphine (Diprenorphine HCl® 12 mg/ml and Large Animal Revivon® 3 mg/ml, Vericore Veterinary Products, Novartis Animal Health UK Ltd.). For reversal of etorphine effects in moose, the volume of diprenorphine should be equivalent to the total volume of etorphine administered. If etorphine is combined with xylazine or medetomidine, the effects of the alpha-2 agonist should be reversed by atipamezole (Antisedan® 5 mg/ml, Orion Pharma Animal Health, Turku, Finland) at 1 mg per 10 mg xylazine or 5 mg per mg medetomidine (Kreeger et al. 2002).

Thiafentanil

We are aware of only two reports on the use of thiafentanil for immobilization of free-ranging moose. In one study average down time in moose (n = 18) darted with a standard dose of 10 mg thiafentanil was 1.5 min compared to 4.5 min in moose (n > 100) injected with a standard dose of 4.5 mg carfentanil (Stanley et al. 1989). Reversals of immobilization were achieved with either nalmefene or diprenorphine (no data on antagonist doses was provided). Renarcotization in animals immobilized with thiafentanil was not observed and the authors state that the elimination half-life of thiafentanil is only half as long as the elimination time of carfentanil. Later, McJames et al. (1994) reported that a standard dose of 10 mg thiafentanil was used to immobilize moose from a helicopter in winter. The mean induction time in 59 moose immobilized after one injection was 3.6 min. The 10 mg dose was effective for large bulls and safe for calves. Three animals required a second dart to become immobilized and received a total dose of 20 mg thiafentanil. Reversals after different doses of nalmefene (50 and 300 mg) and naltrexone (50 and 100 mg) were rapid and complete with no residual ataxia. Mean standing times ranged from 1.9 to 2.4 min after intramuscular administration of the antagonist in all groups. Renarcotization was not seen and no deaths occurred. Although more studies on its efficacy and safety are required, there are strong indications that thiafentanil may be a very useful drug for immobilization of moose in the future: small volume (1 ml), induction time is rapid, duration of action is short, no major clinical side effects have been reported, and renarcotization has not been observed. This view is supported by several studies on thiafentanil in other

artiodactylid species (Stanley et al. 1988, Janssen et al. 1993, McJames et al. 1993, Citino et al. 2001, Grobler et al. 2001, Kreeger et al. 2001, Citino et al. 2002). Currently, thiafentanil is only available for investigational purposes (A3080® 10 mg/ml, Wildlife Pharmaceuticals Inc.).

Medetomidine-Ketamine

Studies on medetomidine (MED), ketamine (KET), and atipamezole (ATI) in free-ranging moose were performed in Norway and Finland from 1992 to1997. Although some of the data from these studies have been printed in non-indexed sources (Arnemo et al. 1994, Arnemo 1995, Arnemo et al. 1996), they are not easily available to the scientific community. In addition, a lot of useful information is not yet published (J. M. Arnemo and T. Soveri, personal observations). A summary of the results is therefore included here.

In summer, 30 mg MED + 400 mg KET (n = 15), 30 mg MED + 500 mg KET (n = 3), and 40 mg MED + 500 mg KET (n = 4) were used to immobilize adults from ground (on foot, stalking, and from a motor vehicle). For reversal, all animals received 5 mg ATI per mg MED, half intravenously or intramuscularly and half subcutaneously. Only a few of the animals were actually seen going down and to avoid stress and excitement during induction, the standard procedure was to wait for 10 min after darting before tracking with a dog was initiated. Mean time (range) from darting until the animal was found was 18 (1-35) min for animals completely immobilized after one dart injection. Mean estimated distance (range) covered after darting was 300 (10-750) m. Two animals darted with 30 MED + 500 KET and one animal darted with 40 mg MED + 500 mg KET required reiteration with a full initial dose to become completely immobilized. One cow in poor body condition darted with 30 mg MED + 400 mg KET developed periodic apnea after 45 min and was treated with ATI (half intravenously and half subcutaneously) to reverse immobilization. One cow injected twice with 40 mg MED + 500 mg KET apparently stopped breathing 40 min after the initial darting and was treated with doxapram (Dopram® 20 mg/ml, Wyeth Lederle, Wyeth-Ayerst International Inc., Philadelphia, Pennsylvania, USA) at 1 mg/kg intravenously and ATI (half intramuscularly and half subcutaneously). One cow (400 kg) was found drowned in a small creek 13 min after darting with 40 mg MED + 500 KET, 200 m from where she was shot. Necropsy (National Veterinary Institute, Oslo, Norway) revealed no underlying pathological conditions. No other immediate mortalities occurred. Recoveries were uneventful and all animals were standing in less than 11 min after administration of ATI. Animals monitored by radiotracking (n = 17) survived at least 2 months post capture. Data on physiologic parameters (rectal temperature, heart rate, respiratory rate, and relative arterial oxygen saturation) are found in Arnemo et al. (1994) and Arnemo (1995).

In winter, 30-40 mg MED + 500 mg KET induced complete immobilization in 6 out of 8 adult cows darted from a motor vehicle at a bait. Four animals were observed going down after a mean induction time (range) of 7 (4-11) min while 2 individuals were found after 22 and 43 min, respectively. In two animals the initial dose did not induce recumbency, one of them was manually restrained while the other was captured after an additional dose of 6 mg etorphine. All animals received 5 mg ATI per mg MED for reversal. Recoveries were uneventful and all animals were on their feet in less than 13 min after administration of ATI. All animals were monitored by radiotracking and survived for at least 9 months post capture. Physiologic data are

found in Arnemo et al. (1994).

In winter, 8 adult cows and 5 bulls were darted from a helicopter with 30 mg MED + 400 mg KET (n = 2) or 40 mg MED + 500 mg KET (n = 11). Two animals receiving the highest dose required reiteration with a full initial dose. Mean time (range) from darting to recumbency in animals completely immobilized after one injection was 8 (4-15) min. Two animals injected with the highest dose showed signs of respiratory depression with shallow breathing and periodic apnea. Reversals were achieved with ATI at 5 mg per mg MED injected half intramuscularly and half subcutaneously. One cow that apparently stopped breathing 40 min after darting was treated with doxapram at 1 mg/kg intravenously in addition to ATI, while inspirations were induced by manual chest compressions. This individual recovered completely. Twelve of the animals were on their feet in less than 10 min after administration of ATI. One bull immobilized with the lowest dose became fully alert after injection of ATI but was apparently unable to get up. The bull was net-lifted with a helicopter to a safe area and was left in sternal recumbency 2.5 hrs post darting. Next morning the bull was tracked for > 1 km with the helicopter but was not observed. All animals were monitored by radiotracking and survived for at least 6 months post capture. Based on clinical examination of each individual and the actual body mass of the bull that remained recumbent (240 kg), all animals in this part of the study were in very poor body condition. Physiologic data are found in Arnemo et al. (1994).

A major part of the MED-KET and ATI evaluation was carried out during 5 winters in Finland from 1993 to 1997. A total of 92 moose were darted from a helicopter: 26 calves (10 females, 16 males), 20 yearlings (17 were of known age) (7 females, 13 males), 26 adult cows, and 20 adult bulls. Standard initial doses were 30 mg MED + 400 mg KET in calves, 40 mg MED + 400 KET in yearlings, and 40 or 50 mg MED + 600 KET in adults. Mean times (range) from darting to recumbency in animals that became completely immobilized after one dart injection were 4.4 (2-7) min in calves (n = 20), 7.6 (5-11) min in yearlings (n = 14), 6.0 (3-10) min (n = 22) in cows, and 5.9 (1-12) min in bulls (n = 14). Animals that required additional dosing to induce complete immobilization, animals that were darted more than once due to malfunctioning darts or bounce offs, and animals that were not observed going down, were not included in the analyses. No animals died during immobilization. However, a total of 4 animals (4.3%) died or were euthanized within 24 hrs post capture. One bull was unable to get up after administration of ATI and was found dead next day. Necropsy (National Veterinary Institute, Oulu, Finland) showed very poor body condition, massive lungworm infestation, and signs of circulatory failure. One small calf which was unable to get up after injection of ATI was euthanized next day. Necropsy (National Veterinary Institute) showed very poor body condition, osteoporosis, and fractures in scapula and metatarsus. One small calf and one yearling, both in very poor body condition, recovered after injection of ATI but were found dead next day 100 and 300 m, respectively, from the marking place. Necropsies were not carried out on these two individuals. Three of the deaths (both calves and the yearling) occurred in 1996, a year with extremely harsh winter conditions which caused poor body conditions in most of the captured animals. All animals were monitored by radiotracking and no other mortalities occurred within 2 months post capture. The complete set of data from this trial, including serum biochemistry, is currently being analyzed for publication elsewhere.

Other Drugs

Drug combinations like xylazine-ketamine, xylazine-tiletamine/zolazepam, or medetomidine-tiletamine/zolazepam are not recommended for capture of free-ranging moose (Franzmann 1982, Kreeger et al. 2002; J. M. Arnemo and T. J. Kreeger, unpublished data).

Rapid induction is of paramount importance in wildlife capture operations and the enzyme hyaluronidase has been used to increase drug absorption rate (Haigh 1979, Kreeger et al. 2002). However, induction time is more dependent on the injection site and drug dose, and hyaluronidase is probably of benefit only for sub-optimal hits and doses. In addition, there are concerns regarding the stability of the drug mixture and also the epizootiological aspects of the enzyme that is a biological product extracted from bovine testes.

Moose are often captured during low ambient temperatures in winter and propylene glycol has been added to immobilizing mixtures (xylazine-tiletamine/zolazepam) to avoid freezing (Kreeger et al. 1995). However, in moose darted with 7.5 mg etorphine (1 ml) from a helicopter in winter using standard remote drug delivery equipment (Dan-Inject®, Børkop, Denmark), addition of propylene glycol (0.5 ml) caused delayed inductions (J. M. Arnemo, unpublished data). Ten adult cows were immobilized on 10-11 December 1999, half of them received etorphine and propylene glycol (group 1) and the other half received etorphine only (group 2). Mean times (range) from initial darting to recumbency were 18 (11-32) min in group 1 and 5 (2-7) min in group 2. Two animals in group 1 required a second dart for immobilization. Mean estimated distances (range) covered after darting were approximately 3 (2-5) km in group 1 and 0.4 (0.1-0.7) km in group 2. The use of propylene glycol as an antifreeze in etorphine mixtures cannot be recommended for moose immobilization.

MONITORING AND RISKS

Anesthetic Monitoring

After capture, immobilized moose should be examined and monitored by a wildlife veterinarian. Clinical problems or injuries should be treated according to established standards in veterinary medicine (Kreeger et al. 2002). Dart wounds are extremely rare in moose if lightweight darts with low impact energy and modern remote drug delivery equipment are used. To avoid bloat and to reduce the risk of regurgitation and aspiration of rumen contents, captured moose should be kept in sternal recumbency with the head higher than the body and the nose lower than the neck. The use of head covers/blinds and ear plugs will reduce stress in animals during handling. For safety reasons, the feet of immobilized animals should be hobbled.

Franzmann et al. (1984) established baseline values for rectal temperature (RT), heart rate (HR), and respiratotory rate (RR) in chemically immobilized moose and safe expected ranges were 38.4-38.9 ºC, 70-91 beats/min, and 13-40 respirations/min, respectively. Critical values for corrective actions were RT 40.2 ºC, HR 102 beats/min, and 40 respirations/min. Based on personal experience with moose immobilization, we consider these values to be conservative. Assessment of respiration in immobilized animals can be done by monitoring of the relative arterial oxygen saturation (SpO_2) with a pulse oximeter. Hypoxemia is defined as $SpO_2 < 90\%$. In field situations, however, SpO_2 values markedly below 90% are often recorded, apparently with no harm to the animal. A critical SpO_2 value has not been defined but one of the authors (J. M. Arnemo) usually institutes corrective actions (administration of supplemental oxygen, respiratory stimulants, or specific antagonists) when the SpO_2 falls

below 70%. The trend of SpO_2 values is probably more important than the absolute values and if the SpO_2 steadily decreases, it can be presumed that the animal is in some sort of respiratory crisis (Kreeger et al. 2002).

Exertional Myopathy

Exertional myopathy (commonly referred to as capture myopathy) is a well-known, usually fatal syndrome in free-ranging artiodactylids (Spraker 1993, Williams and Thorne 1996). Exertional myopathy may be caused by several factors, such as stress, chasing, restraint, and transportation. Clinical signs of exertional myopathy may become apparent during the capture process or may occur within hours postcapture. It is, however, important to note that the pathologic manifestations of exertional myopathy can be delayed for up to a month following capture before the animal eventually dies (Spraker 1993, Williams and Thorne 1996). Any evaluation of capture methods and drugs in free-ranging moose should therefore include a minimum of 4 weeks follow-up by radiotelemetry to detect delayed mortalities caused by exertional myopathy.

Risk of Chemical Capture

In moose, chemical immobilization is an invaluable tool both for management and research. Since the pioneer days of the 1950s and 1960s, a large number of free-ranging moose have been chemically immobilized for various purposes. During the initial phase of moose chemical capture, mortality rates were often very high. In some instances as much as 26% of the animals died, either during the capture process, during transport, or shortly after release (Franzmann 1982). Main causes of mortality were respiratory depression, cardiovascular collapse, hyperthermia, trauma, stress, and exertional myopathy.

Efficient drugs and antagonists have been available for reversible immobilization of moose for at least 2 decades. In addition, remote delivery systems and lightweight darts were developed for non-traumatic administration of drugs. Access to portable and easy to use monitoring devices like pulse oximeters further improved animal safety during field anesthesia. In spite of this progress, reported mortality rates often range from 6 to 19% in moose captured with carfentanil combinations (Roffe et al. 2001). In contrast, only 7 animals (0.5%) died during 1,464 immobilizations carried out with etorphine from helicopter over a 19-year period in Norway (Arnemo et al. 2001; J. M. Arnemo, unpublished data). More than 97% of the animals in this study were monitored by radiotracking and no mortalities due to resedation, predation, or exertional myopathy occurred.

In a review of stress and exertional myopathy in artiodactylids, Spraker (1993) stated that a mortality rate greater than 2% during trapping is not acceptable. We believe that this rule should be applied also to chemical capture situations: A capture related mortality rate greater than 2% during chemical immobilization and a 1-month follow-up period is not acceptable for routine captures of moose and requires that the capture protocol be re-evaluated. At least this should be the rule of thumb when a large number ($n > 100$) of free-ranging moose are being chemically immobilized.

Human Safety

Although animal welfare is important, the first concern when dealing with wild animals should be the safety of humans (Fowler 1995). Carfentanil, etorphine, and thiafentanil are up to 10,000 times more potent than morphine and minuscule amounts of drug are theoretically lethal to people (Kreeger et al. 2002). Extreme care should therefore be taken when working with po-

tent opioids and lost darts should be of major concern. Other drugs and drug combinations at doses prepared for moose are also potentially dangerous and all personnel involved in moose captures should therefore be qualified to perform first aid on humans. A brief update on human medical treatment following accidental exposure to immobilising drugs is found in Kreeger et al. (2002). Most drugs used for moose capture are colourless. As a safety precaution, drugs may be coloured to make it easier to detect leakage from vials, needles, darts, and injection sites. Congo red and cobalt blue are commonly used for this purpose (Nielsen 1999). The use of dart guns requires an understanding of ballistics and gun safety and readers are referred to recent publications on wildlife chemical immobilization (Nielsen 1999, Kreeger et al. 2002). Overviews of safety aspects regarding helicopter operations were provided by Nielsen (1999).

RECOMMENDATIONS

For routine immobilization of free-ranging moose, we recommend carfentanil at 0.01 mg/kg or etorphine at 7.5 mg total dose per adult. At these doses most animals are able to maintain sternal recumbency. We do not advocate combining opioids with xylazine or other sedative drugs because this will often induce lateral recumbency and thereby increase the risk for tympany, regurgitation, and aspiration of rumen contents. Carfentanil and etorphine have a wide safety margin in moose and the risk of severe anesthetic side effects during immobilization is minimal. Medetomidine-ketamine is a useful non-opioid alternative. Neuromuscular blocking agents should never be used in moose. In our opinion, a mortality rate greater than 2% is not acceptable for routine captures of moose.

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