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EVALUATION OF ISOFLURANE AND PROPOFOL ANESTHESIA FOR INTRAABDOMINAL TRANSMITTER PLACEMENT IN NESTING FEMALE CANVASBACK DUCKS

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ABSTRACT: Heart rate, occurrence of apnea, body temperature, quality of anesthesia and nest abandonment were compared during either propofol or isoflurane anesthesia of nesting female canvasback ducks (*Aythya valisineria*) at 15 to 18 days of incubation. One hundred eighteen canvasbacks were assigned randomly to three treatments so that nest abandonment could be compared among treatments from May to July 1995 and 1996. Sterile dummy silicone implants were placed during an abdominal laparotomy while ducks were anesthetized with either propofol or isoflurane, or ducks were flushed from the nest but not captured (control). Propofol was delivered through an intravenous catheter, while isoflurane was delivered in oxygen. Propofol provided smooth, rapid induction and recovery, whereas ducks recovering from isoflurane tended to struggle. At the nest, ducks in the propofol group were given additional boluses until they were lightly anesthetized, whereas birds that received isoflurane were released. All birds survived surgery but one death occurred prior to surgery in 1995 using propofol during a period without ventilation and monitoring. Adequate artificial ventilation is recommended to prevent complications. Heart rate declined significantly in both years during isoflurane anesthesia and in 1995 during propofol anesthesia but not 1996. During both isoflurane and propofol anesthesia, body temperature declined significantly over time. Nest abandonment was significantly different among treatments and occurred in all treatment groups in both years, but propofol (15%) and control groups (8%) had lower than expected abandonment compared to isoflurane (28%). Propofol offers several advantages over isoflurane for field use; equipment is easily portable, lower anesthetic cost, and ambient temperature does not alter physical characteristics of the drug. Advantages over isoflurane, including lower nest abandonment following intraabdominal radio transmitter placement, make propofol a good anesthetic choice for field studies.

Key words: Anesthesia, *Aythya valisineria,* canvasback, isoflurane, nest abandonment, propofol, surgery, telemetry.

INTRODUCTION

Radiotelemetry is used extensively in waterfowl research, and intraabdominal transmitters are often preferred over externally-mounted transmitters (Korschgen, 1984). Compared to other types of transmitter attachment, intraabdominal transmitters appear to have less adverse effects on normal behavior (Greenwood and Sargeant, 1973; Pietz et al., 1993), reproductive effort (Pietz et al., 1993; Rotella et al., 1993), return rates (Ward and Flint, 1995; Dzus and Clark, 1996), diving, feeding, or flight (Greenwood and Sargeant, 1973; Gilmer et al., 1974; Perry, 1981) and plumage or insulatory effects of feathers (Greenwood and Sargeant, 1973; Perry, 1981). Time and stress associated with handling, capture, transport, surgery and release may also interfere with normal reproductive behavior and lead to nest abandonment. Anesthesia has been employed to facilitate transmitter placement (Olsen et al., 1992), reduce stress during handling and decrease nest abandonment (Smith et al., 1980; Rotella and Ratti, 1990). Methoxyflurane has been used without a vaporizer to reduce nest abandonment by placing the anesthetic on gauze, but inability to control depth of anesthesia may result in respiratory depression and mortality (Smith et al., 1980; Rotella and Ratti, 1990). Violent recoveries associated with methoxyflurane-anesthesia (Rotella and Ratti, 1990) make this technique unsuitable for over-water nesting species, such as canvasback ducks (*Aythya valisineria*). Like other inhalants, methoxyflurane also poses a significant human health risk (Baden and Rice, 1990).

Isoflurane and methoxyflurane are often used to anesthetize birds during surgery but require expensive equipment such as a vaporizer and oxygen delivery system (Brinkman and Burch, 1964; Olsen et al., 1992). Isoflurane is often the anesthetic of choice for birds because rapid reversal results in a wide margin of safety and it is well tolerated by all species (Ludders et al., 1990). However, recovery from isoflurane-anesthesia is too rapid to allow placement of ducks into their natural environment prior to complete recovery. This may cause unacceptably high abandonment when attempting to place birds on their nests following surgery, although this has not been tested.

Propofol is an intravenous agent that is metabolized rapidly and requires continuous administration to produce anesthesia (Sebel and Lowdon, 1989). Propofol anesthesia provides adequate muscle relaxation and is suitable for minor procedures, without residual sedation (Shafer, 1993). Intermittent bolus injections or continuous infusion is required to maintain anesthesia (Adam et al., 1983). Frequency and dose of the bolus determines degree of oscillation of propofol blood concentrations and therefore depth and length of anesthesia (Cockshott et al., 1992). Variability in control of anesthetic depth during maintenance may be caused by individual variation in dose requirements (De Grood et al., 1985). Propofol causes dose-dependent respiratory depression in birds and apnea of short duration and hypercapnia may follow a rapid bolus injection (Fitzgerald and Cooper, 1990; Mama et al., 1996; Lukasik et al., 1997; Machin, 1997; Schumacher et al., 1997; Machin and Caulkett, 1998a, b). With assisted respiration and appropriate monitoring during anesthesia, the rapid induction and recovery with no residual sedation make propofol an excellent choice for field anesthesia.

The main objective of this study was to compare heart rate, respiratory depression, and body temperature of free-ranging female canvasback ducks during propofol- and isoflurane-anesthesia. We examined nest abandonment rates associated with anesthesia and surgery. We also describe a general anesthetic protocol for waterfowl using propofol for surgical placement of radio transmitters for use in either the field or a clinical setting.

MATERIALS AND METHODS

All ducks were treated in accordance with guidelines of the Canadian Council on Animal Care (1993) as defined by the Guide to the Care and Use of Experimental Animals and the study was approved by the University of Saskatchewan Animal Care Committee (Saskatchewan, Canada). Work was conducted from May to July 1995 and 1996 on a 200 km^2 study area near Minnedosa (Manitoba, Canada; 50°10′N, 99°47′W). Nests of female canvasback ducks were located by systematically walking through emergent vegetation surrounding wetlands on the study area. In most brood survival studies, females are equipped with transmitters during mid-to-late incubation to reduce the loss of equipment and information because of predation and to reduce the probability of nest abandonment (Gloutney et al., 1993). Therefore, female canvasbacks were captured at 15 to 18 days as determined by egg candling (Weller, 1956) of an average 25 day natural incubation period (Bellrose, 1976).

Female canvasbacks were assigned randomly to one of three treatments: (1) propofol (Rapinovet, Shering-Plough Animal Health, Pointe-Claire, Québec, Canada), (2) isoflurane (AErrane, Anaquest, Point Claire, Québec, Canada) and (3) control (flushed from nest but not captured). Canvasback ducks were captured using nest traps (Weller, 1957). Sterile dummy silicone implants weighing 15 to 18 g were surgically implanted while birds were anesthetized with either propofol (n = 39) or isoflurane (n = 39). Birds in the control group (n = 40) were considered to be normal with minimal intervention since they were flushed from the nest and not handled.

Prior to use in the field, we developed and evaluated anesthetic techniques with captive mallard (*Anas platyrhynchos*; Machin, 1997; Machin and Caulkett, 1998a, b) and captive

TABLE 1. Quantity of propofol (mg/kg) administered intravenously and isoflurane vaporizer settings (%) during anesthesia of female canvasback ducks in late incubation for surgical placement of intraabdominal transmitters.

Anesthetic	Yr	*n*[a]	Time interval (min)			
			0–5	5–10	10–15	15–20
Propofol	1995	18	18.9 ± 1.7[b]	3.7 ± 1.6	4.1 ± 1.0	1.7 ± 2.1
Propofol	1996	21	24.3 ± 5.4	1.4 ± 1.8	2.5 ± 2.4	2.0 ± 1.7
Isoflurane	1995	18	3.7 ± 0.3	2.6 ± 0.4	2.2 ± 0.4	2.1 ± 0.5
Isoflurane	1996	21	3.9 ± 0.3	3.1 ± 0.3	3.0 ± 0.2	1.6 ± 1.4

[a] Sample size.
[b] Mean ± standard deviation.

canvasback ducks (Machin, 1997). For intravenous (IV) propofol delivery, ducks were held in lateral recumbency with the lower leg held in extension to place a catheter in the medial metatarsal vein. Induction of anesthesia was accomplished by administering 10 mg/kg of propofol over 1 min. Depth of anesthesia was assessed by opening the bill and pulling the tongue forward. If the duck was capable of struggling or lifting its head additional boluses of 1 to 2 mg/kg were given until a non-cuffed endotracheal tube (3.0 to 3.5 mm, Mallinkrodt Medical Inc., St Louis, Missouri, USA) could be placed. Additional boluses of propofol (1 to 2 mg) were given as needed throughout the procedure to maintain an adequate level of anesthesia (Table 1). In 1995, birds receiving propofol were ventilated when they became apneic using a pediatric self-inflating resuscitation apparatus (AMBU bag). In 1996, all birds were ventilated throughout the procedure. Ventilation was performed so that there was visible expansion of the thorax every 5 sec.

Isoflurane was delivered through a non-rebreathing system by an Isotec 3 vaporizer (Ohmeda, BOC Health Care, West Yorkshire, England). Anesthesia was induced with isoflurane starting at 1% and stepped up to 5% with an oxygen flow of 2 L/min. Following induction, birds were intubated with a non-cuffed endotracheal tube. Anesthesia was maintained at 1.5 to 3.5% with oxygen flow rate of 1 L/min (Table 1). Birds that became apneic were ventilated with a 0.5 L rebreathing bag attached to the circuit.

After induction, the bird was placed in dorsal recumbency and prepared for surgery. During preparation and surgery, depth of anesthesia was assessed by monitoring (1) heart rate using an esophageal stethoscope, (2) nictitating membrane movements, (3) swallowing or coughing, (4) response to stimuli and (5) movement. In both groups, anesthetic delivery was adjusted if there was a sudden change in heart rate or any of the above indicators of light anesthesia were present to maintain the bird at a constant level of anesthesia. The incision site of all birds was infiltrated with 2 mg/kg, 0.5% solution of bupivacaine (Marcaine, Sanofi Winthrop, Markham, Ontario, Canada) to help control operative and post-operative pain. During anesthesia and surgery, anesthetic dose, heart rate, and complications were recorded by observers every 5 min for all birds.

The surgical procedures were that reported by Olsen et al. (1992). When ambient temperature was less than 16 C, birds were placed on hot water bottles to aid in maintaining body temperature. Surgical instruments were sterilized using 1:200 aqueous solution of Savlon Hospital Concentrate (Ayrst Laboratories, Saint Laurent, Québec, Canada) and the solution was changed after every fourth surgery. Surgical instruments were wiped with sterile gauze to remove Savlon solution before use to prevent chemical irritation of the tissues. Dummy radio transmitters were sterilized using ethylene oxide gas. Surgeries were performed within 500 m of the nest. In 1995, a rectal thermometer was unable to register most temperatures; therefore, in 1996, a temperature probe, placed at least 15 cm into the esophagus was used to monitor body temperature. Surgical time, anesthesia time and time to extubation were recorded in both years. Time from removal from the nest trap to time of release (total time held) was recorded only in 1996.

After the anesthetic was discontinued, heart rate and respiratory rate were monitored in both groups until normal breathing resumed. Oxygen flow rate was maintained at 1 L/min for birds receiving isoflurane and ventilation was provided as necessary for ducks in both groups. The endotracheal tube was removed when the bird began to lift its head to cough or swallow. Respiration was monitored for a few minutes following extubation to ensure that ventilation was maintained. During recovery from anesthesia, ducks were leg banded and received a unique combination of nylon nasal markers of varying color and shape (Lokemoen and Sharp, 1985). All ducks were weighed to the nearest 5 g using Pesola spring scales and the weight was adjusted for the weight of the dummy transmitter. Ducks were then taken back to the nest. At the nest, ducks in the propofol group were given additional anesthetic (2 to 9 mg/kg) until depth of anesthesia was sufficient to allow removal of the catheter. Respiratory rate was monitored while bleeding was stopped by applying Blood Stop Powder (Dominion Veterinary Laboratories LTD., Winnipeg, Manitoba, Canada) and manual pressure. Propofol group ducks were left to recover on the nest while ducks in the isoflurane group were released on the nest after recovery.

Prior to each field season (1 to 2 mo prior to use), ampules containing 20 ml of propofol were divided aseptically in a laminar flow hood into three 6 ml and one 2 ml aliquots. Aliquots were placed into vacutainers with no additive and sterile interior (Becton Dickson Vacutainer Systems, Franklin Lakes, New Jersey, USA). The last vacutainer filled was submitted to the Western College of Veterinary Medicine Diagnostic Laboratory for culture 7 days after splitting to ascertain whether microorganism contamination had occurred. In addition, 60 used vials chosen randomly were also submitted for culture at the end of the field season.

Monitoring for nest abandonment in all canvasback groups was accomplished by recording nest temperature every 4.6 min for 6 days after treatment using HOBO XT Temperature Data Loggers (Onset Instruments Corp., Pocasset, Massachusetts, USA) attached to a thermistor implanted into a hollow dummy egg. The dummy egg was anchored to a metal rod measuring at least 15 cm and placed in the center of the clutch. Nests were visited 6 days after surgery to retrieve the HOBO Temp and to determine nest fate (abandoned, active or destroyed). Nests were considered abandoned if the temperature pattern indicated that a bird did not return to the nest following surgery (isoflurane group) or flushing (control group). In the propofol group, nests were considered abandoned if the bird did not return after leaving the nest for the first time following placement on the nest.

Logistic regression was employed to determine whether nest abandonment varied with year, treatment and the interaction of these two variables. Chi-square tests were used to determine if nest abandonment varied with treatment and to compare with results in a study by Arnold et al. (1995). Repeated measures ANOVA (proc GLM; SAS Institute Inc., 1985) to evaluate variation in heart rate and where significant differences were found, a contrast statement was used to compare baseline (0 min) and subsequent values (5, 10 and 15 min). Comparisons of body temperature at the start and end of anesthesia were made using a paired *t*-test. We considered each year separately when analyzing physiological data for three important reasons. First, there was a yearly observer effect because of differences in experience and knowledge. Second, surgery, anesthesia and recovery times differed. Finally, data collection was more standardized in 1996. Tests were executed on SAS (SAS Institute Inc., 1985), and STATISTIX (Analytical Software, 1994). Results were considered significant when $P \leq 0.05$.

RESULTS

In the majority of the ducks, propofol provided smooth, rapid induction and recovery, whereas birds recovering from isoflurane tended to struggle. However, three canvasback ducks had excitatory movements during induction which were characterized by rigid extension of the neck, generalized tremors and paddling of the hindlimbs. These movements subsided after a few minutes and with continued administration of propofol. All birds survived surgery. One death occurred prior to surgery using propofol in 1995 during a period when ventilation and monitoring of the duck was inadvertently stopped. This bird is not included in the analysis. One canvasback duck in the control group in 1996 was found dead on the nest and was likely killed by a mink (*Mustela vison*). This bird was included in the analysis as incubation had continued for 18 hr after placement of the HOBO.

Minor complications included kinked catheters preventing propofol delivery which was corrected by straightening the catheter. Cardiac arrhythmias were noticed following kinking of endotracheal tubes in both anesthetic groups. Straightening of the tube and ventilating the duck resolved the arrhythmia.

Most canvasback ducks developed apnea during isoflurane-anesthesia. In 1995, three birds did not require assisted ventilation and 15 ducks developed apnea after $\bar{x} \pm SD = 4.7 \pm 3.4$ min. Whereas in 1996,

TABLE 2. Heart rates (beats/min) during anesthesia (intravenous propofol or isoflurane delivered in oxygen) of female canvasback ducks captured in late incubation for surgical placement of intraabdominal transmitters.

Anesthetic	Yr	*n*[a]	Time (min) 0	5	10	15
Propofol[b]	1995	18	310 ± 37[c]	294 ± 49[d]	259 ± 58[d]	245 ± 45.5[d]
Propofol	1996	20	237 ± 30	233 ± 39	222 ± 34	212 ± 39
Isoflurane[b,e]	1995	17	205 ± 30	188 ± 21	176 ± 22[d]	173 ± 19[d]
Isoflurane[b]	1996	20	206 ± 67	172 ± 48[d]	167 ± 33[d]	175 ± 39

[a] Sample size.
[b,e] Values significantly different among groups ($P \leq 0.05$) (repeated measures ANOVA).
[c] Mean ± standard deviation.
[d] Significant decline compared to baseline (0 min, $P \leq 0.05$) (repeated measures ANOVA).

only one duck had spontaneous respiration and 20 ducks developed apnea after 3.75 ± 3.9 min. Ducks that received propofol had spontaneous respiration in 1995 but were ventilated to ensure safety in 1996. Heart rates declined significantly over time in birds anesthetized with isoflurane in both years (repeated measures ANOVA, 1995, df = 3,39, F = 7.22, $P = 0.0006$ and 1996, df = 3,48, F = 4.28, $P = 0.028$). Whereas, heart rates declined significantly for ducks anesthetized with propofol in 1995 (repeated measures ANOVA, df = 3,33, F = 16.84, $P = 0.001$) but not 1996 (repeated measures ANOVA, df = 3,27, F = 2.26, $P = 0.1$). Heart rates during isoflurane-anesthesia did not differ significantly between 1995 and 1996 (repeated measures ANOVA, df = 3,87, F = 0.63, $P = 0.53$), whereas propofol-anesthetized ducks had higher heart rates in 1995 than in 1996 (repeated measures ANOVA, df = 3,60, F = 5.31, $P = 0.003$). In addition propofol-anesthetized ducks in 1995 had heart rates significantly higher than ducks anesthetized with isoflurane in 1995 (repeated measures ANOVA, df = 3,72, F = 5.43, $P = 0.002$, Table 2).

Body temperature dropped significantly during anesthesia and surgery, despite the use of hot water bottles for some birds (Table 3). One canvasback had a body temperature over 42 C at induction and was placed on a cold water bottle during the procedure. On two occasions the induction period with isoflurane was prolonged (>10 min). Ambient temperature was <12 C and packing the isoflurane vaporizer with hot water bottles appeared to improve induction.

Equipment required for propofol anesthesia was less cumbersome and less ex-

TABLE 3. Temperature during anesthesia (intravenous propofol or isoflurane delivered in oxygen), total time for surgical procedure, total anesthesia time, time to extubation following end of anesthesia and total holding time for female canvasback ducks captured in late incubation for surgical placement of intraabdominal transmitters.

Anesthesia	Yr	*n*[a]	Start temperature (C)	End temperature (C)	Surgery time (min)	Total anesthesia time (min)	Time to extubation (min)	Total holding time (min)
Propofol	1995	18	—	—	10.7 ± 1.8	16.8 ± 2.8	6.7 ± 2.3	NR[d]
Propofol	1996	21	41.0 ± 0.7*[bc]	40.6 ± 0.9*	8.4 ± 1.7	9.4 ± 2.3	4.4 ± 3.1	48.0 ± 3.9
Isoflurane	1995	18	—	—	10.8 ± 2.6	20.3 ± 4.8	8.8 ± 2.9	NR
Isoflurane	1996	21	40.7 ± 0.7*	39.6 ± 0.8*	8.4 ± 1.2	14.0 ± 1.9	6.3 ± 2.4	49.2 ± 8.7

[a] Sample size.
[b] Paired *t*-test, *$P \leq 0.05$, comparing start and end temperatures.
[c] Mean ± standard deviation.
[d] NR = not recorded.

TABLE 4. Nest abandonment of female canvasback ducks captured in late incubation following random assignment to three treatment groups. Birds were flushed from the nest (control) or implanted surgically with intraabdominal dummy radio transmitters during anesthesia with either intravenous propofol or isoflurane delivered in oxygen.

Year	Treatment groups					
	Propofol	*n*[a]	Isoflurane	*n*	Control	*n*
1995	3 (17)[b]	18	5 (28)	18	2 (10)	19
1996	3 (14)	21	6 (29)	21	1 (5)	21
Total	6 (15%)	39	11 (28%)	39	3 (8)	40

[a] Sample size.
[b] Number of nests abandoned (% nests abandoned).

pensive than that required for inhalant anesthesia. Cost of the AMBU bag required for ventilation during propofol anesthesia was U.S. $28.89, whereas, a new precision vaporizer was $2,200.00 (however, refurbished vaporizers may reduce cost). The total anesthetic cost of propofol and consumables were $4.22/duck compared to $6.93/duck for isoflurane and oxygen. Propofol alone cost $2.22/duck not including the additional cost of catheter, infusion plug, syringes etc. ($2.00/duck), whereas isoflurane was $5.93 and required an additional cost of oxygen and tank rental ($1.00/duck). Costs reflect Canadian prices and exchange rates at the time the study was done. None of the vacutainers submitted for culture either prior to the field season or after the field season had microorganisms identified.

Nest abandonment occurred in all treatment groups in both years (Table 4). Ducks in the propofol and isoflurane groups had similar handling times (Table 3). No difference in nest abandonment was found between years (logistic regression, $P = 0.55$), nor was there a year by treatment interaction ($P = 0.83$). When these terms were dropped from the model, a weak treatment effect was detected (logistic regression, $P = 0.06$), owing to the greater nest abandonment ($P = 0.02$) in the isoflurane group. These analyses were appropriate because the data fit the logistic models adequately (model goodness of fit, Ps > 0.8). Categorical analyses confirmed these findings; there was a significant difference among treatments in nest abandonment ($\chi^2 = 6.115$, 2 df, $P = 0.047$), with propofol and control groups having lower than expected abandonment. Since nest abandonment in propofol and control groups did not differ ($\chi^2 = 1.22$, 1 df, $P = 0.27$), this indicates that the former relationship between groups was driven by higher than expected abandonment in the isoflurane group.

A comparison of nest abandonment in the two surgery groups in this study was made with Arnold et al. (1995) results revealed that surgery produced higher abandonment rates ($\chi^2 = 11.75$, 2 df, $P = 0.003$). However, when results for the propofol group were compared with Arnold et al.'s findings, no significant difference in nest abandonment ($\chi^2 = 1.12$, 1 df, $P = 0.29$) was found, suggesting that the former relationship was driven primarily by the isoflurane group.

DISCUSSION

Propofol provided smooth, rapid induction and recovery from anesthesia in 37 of 40 ducks and excellent muscle relaxation during surgery. However, three of the ducks did experience transient signs of central nervous system excitement (excitement phenomenon) during induction. This excitement phenomenon is not uncommon with propofol administration and can include limb paddling, involuntary, rapid, rhythmic eyeball movements (nystagmus), focal muscle twitching or tremors, hyperextension of the head and neck over the back (opisthotonos), and seizures (Smedile et al., 1996). These have not been associated with long term effects in humans or other animals (Davies, 1991; Smedile et al., 1996). In this study, increase in anesthetic depth resulted in cessation of the excitement, and the three birds that experienced the excitatory movements recovered normally and did not abandon their nests.

Most complications were minor and

were resolved by examining equipment and improving ventilation of birds. Proper ventilation and monitoring during anesthesia is paramount to ensuring safety since propofol produces dose-dependent ventilatory depression in both mammals and birds (Goodman et al., 1987; Fitzgerald and Cooper, 1990; Mama et al., 1996; Machin, 1997; Schumacher et al., 1997; Machin and Caulkett, 1998a, b). Birds anesthetized with isoflurane had longer induction and a more violent recovery than birds anesthetized with propofol. As with propofol, isoflurane-anesthetized birds also required controlled ventilation since most birds developed apnea.

Apnea may result from direct respiratory depressant effects of the anesthetic and/or by relaxation of the muscles of respiration (Ludders et al., 1995). Apnea may also be induced in birds through delivery of high concentrations of oxygen used for delivery of isoflurane anesthesia (Ludders et al., 1995). During induction of anesthesia (isoflurane) in waterfowl, apnea can occur by placing pressure or a mask over the beak. This response is mediated by stimulation of trigeminal receptors in the beak and nares of diving ducks (Butler, 1988). As muscle relaxation is a feature of general anesthesia, assistance in respiration is often required. Degree of muscle relaxation depends on the anesthetic, depth of anesthesia and physical condition of the bird (Ludders et al., 1995). Compression of abdominal and caudal thoracic air sacs by abdominal viscera when the birds are in dorsal recumbency may also restrict ventilation (King and Payne, 1964). Compression of the AMBU or rebreathing bag should result in obvious rising and falling of the thorax as respiratory depression was likely manifested as a reduction in respiratory volume (Goodman et al., 1987).

The significant decline in heart rate during isoflurane anesthesia may be caused by a number of factors including direct cardiac depressant qualities of the anesthetic (Ludders et al., 1990), an artificially elevated heart rate prior to induction from excitement, or apnea on induction resulting in hypoxia and tachycardia (Taylor et al., 1986). Birds anesthetized with propofol in 1995 had high initial heart rates that declined significantly overtime. Hypoventilation in 1995 may have resulted in hypercarbia and/or hypoxia potentially producing tachycardia (Kumar and Srivastava, 1965). Artificial ventilation during anesthesia providing adequate gas exchange and the direct pressure of inflating airsacs may have also contributed to the lower heart rates in 1996 (Morgan et al., 1966). As demonstrated in other studies (Machin, 1997; Machin and Caulkett, 1998a, b), propofol appears to preserve heart rate when there is adequate ventilation.

Surgery and anesthesia resulted in a significant decline in body temperature. Disruption of thermoregulation during general anesthesia and heat loss though the abdominal incision and respiratory tract may be largely responsible (English et al., 1991). However, heat loss was beneficial in the duck that was hyperthermic prior to surgery. Ambient and body temperature should dictate the use of hot or cold water bottles. Hypo- and hyperthermia can contribute to complications and post-operative physiological and behavioral changes (English et al., 1991; Opperman and Bakken, 1997).

Vaporizer settings may not always reflect the amount of volatile anesthetic delivered to the patient because ambient temperature influences the rate of vaporization. Low ambient temperature was responsible for prolonged induction with isoflurane because it decreases the rate of vaporization (Dyson, 1992). When volatile anesthetics are not administered by using a vaporizer, variation in ambient temperatures can result in wide variations in anesthetic depth and may contribute to complications including apnea (Dyson, 1992). Mallard ducks anesthetized with methoxyflurane without a vaporizer can experience respiratory arrest requiring resuscitation and/or death (Rotella and Ratti, 1990).

Cost of propofol including consumables

was less than isoflurane. In this study, all ducks were intubated with endotracheal tubes for safety and to decrease anesthetic cost of isoflurane. The amount and cost of isoflurane would increase if a mask was used to deliver the anesthetic rather than an endotracheal tube because of anesthetic leakage.

As propofol is an aqueous-soya bean oil, glycerol and egg lecithin emulsion it is capable of supporting bacterial growth at room temperature (Berry et al., 1993; McHugh and Roper, 1995) and has been associated with postsurgical infections in humans (Bennet et al., 1995). Unlike most intravenous anesthetics, propofol does not contain any preservatives or antimicrobial agents to retard bacterial growth and refrigeration is not recommended by the manufacturer. Propofol is marketed in 20 ml ampules and may be expensive or impractical to use in animals requiring smaller dosages. Contamination of propofol can be related to poor aseptic technique by not wearing gloves or properly cleaning ampules before opening them, and delays which occur between drawing-up and administration of propofol (Tessler et al., 1992; McHugh and Roper, 1995). Skin contact is often implicated as the source of propofol contamination (McHugh and Roper, 1995). The last vacutainer filled was submitted for culture since it had the longest exposure time and the greatest likelihood of contamination. As no microorganisms were cultured in the vacutainers prior to and after use in the field we believe that the technique described can be used to aseptically store propofol. Aseptic storage can only be confirmed by microbial cultures and must be done prior to administration of propofol. Prevention of infection decreases post-operative morbidity and mortality and is also cost effective.

Use of propofol resulted in less nest abandonment compared to isoflurane. This study suggests that anesthesia at time of release reduces nest abandonment after surgery. Waterfowl anesthetized with isoflurane are completely aware at time of release whereas birds anesthetized with propofol are allowed to recover in their natural environment without human disturbance. A study by Arnold et al. (1995), reported a 10% nest abandonment rate (39 abandoned, 353 did not abandon) in female canvasback ducks following capture and marking with nasal saddles. Surgery produced a significantly higher nest abandonment rate than capture and marking. But, as there was no significant difference between Arnold et al. (1995) results (10%) and the propofol group (15%), the higher than expected nest abandonment rate was due primarily to the higher abandonment rate in the isoflurane group (28%). Stress at time of recovery in the isoflurane group may be responsible largely for the higher nest abandonment rate. Although nest abandonment in the propofol group was not significantly different from Arnold et al. (1995) results, it is unwise to conclude that surgery and anesthesia had no effect. Further investigation with larger numbers of females in treatment groups is required to resolve this issue.

As neither propofol (Thurmon et al., 1994) nor isoflurane (Dohoo, 1990) provide post-operative analgesia, supplemental analgesia is required for surgical procedures. In this study, bupivacaine was administered prior to surgery to provide both intra- and post-operative pain control. Bupivacaine is a potent local anesthetic in mammalian species (Haskins et al., 1996), however, the effectiveness of bupivacaine to provide analgesia is undetermined in avian species. In prey species, the presence and severity of pain may not be recognized by observers (Flecknell, 1994) but it has been demonstrated that birds possess appropriate neurological components for transmitting pain (Gunther and Necker, 1995). As pain from surgery may result in altered behavior and lowered reproductive success this area of work should be expanded.

Propofol offers several advantages over isoflurane for field use; equipment is easily portable, anesthetic cost is reduced, and ambient temperature does not alter physical characteristics of the drug. Isoflurane poses a significant human health risk (Baden and Rice, 1990) and oxygen, required for administration, is classified as a hazardous material and may be subject to transport regulation. Smooth, rapid recovery with propofol allows placement of birds onto nests without fear of drowning in overwater species or loss of eggs and nesting material and reduces nest abandonment. Researchers should be familiar with doses and administration of both propofol and isoflurane prior to use in a field situation. Anesthetic safety is dependant on the administrator familiarity with the techniques and doses required for anesthesia, as well as, species and individual variation in dose requirements. Hypo- and/or hyperthermia may occur during anesthesia. Body temperature should be monitored and abnormalities corrected with the use of cold- and hot-water bags. Adequate artificial ventilation is also required to prevent hypoxia and hypercarbia during anesthesia (Machin and Caulkett, 1998a, b). Advantages over isoflurane, combined with lower nest abandonment following intraabdominal radio transmitter placement make propofol a good anesthetic choice for field studies particularly in remote situations and nesting waterfowl.

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